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The Yellowing of the Fat in Australian Frozen Rabbits: Its Nature and Cause.

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In July, 1926, Dr. Vickery left Australia for further study at Cambridge University as an 1851 Exhibitioner. He was also given a small grant from the fund which the Executive Committee of the Council control as trustees under the Science and Industry Endowment Act. He has now joined the staff of the Council, and will be concerned with the development of research work on food (mainly meat) preservation and transport. The article that follows is descriptive of some investigations he carried out whilst accommodated at the Low Temperature Research Station of the British Food Investigation Board.—ED.

1. Introduction.

An intense superficial yellowness of the exposed fatty tissues of Australian frozen rabbits has frequently been the cause of considerable losses to the trade. This condition, which affects particularly the tissues surrounding the kidneys, is not present at the time of packing. If the effects of the yellowness were limited only to an inferior appearance of the carcasses exposed for sale on foreign markets, the influence on the prices obtained would be inconsiderable, for, naturally, most of the affected fat may be excised, but it is associated with a pungent odour resembling "blown" linseed oil, which frequently makes the surrounding flesh unpalatable.

The colour of the surface of the affected tissues varies from light yellow to dark orange. In the early stages, the yellowness is patchy, but later extends to all exposed surfaces, which become wax-like, and may readily be peeled off the white fat beneath. Even in the advanced stages, however, the discolouration seldom extends below a depth of 2 to 3 millimetres.

The objects of this investigation were to define the conditions favorable for the onset of yellowness, to discover its cause and nature, and then to suggest methods for its elimination. The experimental work will be surveyed only briefly, as a more complete account will shortly be published.

Australia's exports of skinned and unskinned rabbits have assumed considerable proportions, the major part being sold in Great Britain. Table I. gives the quantities and values of the frozen rabbits exported to Great Britain during the years 1924 to 1929.

TABLE I.

Australian Exports of Frozen Rabbits to Great Britain.

Year.	Quantities.	Value.
	cwt.	£
1924	133,798	299,676
1925	188,892	462,788
1926	178,778	434,528
1927	176,933	419,798
1928	146,319	365,907
1929	157,232	396,194

As other defects, such as "perishing," "acid livers," &c., often accompany the yellowing of the fat, it is impossible to estimate accurately the extent of the monetary losses caused by the yellowing alone. Inquiries showed, however, that at least 70 per cent. of the crates in which the rabbits are packed contain affected carcasses, and it is estimated that, throughout each year, the losses resulting from yellowing alone approximate to 5 per cent. of the total value of the pack.

2. Summary of Trade Practice.

The rabbits collected by the trappers are forwarded as quickly as possible to the packing sheds, where they are inspected, graded, and packed gut to gut in shallow wooden crates. The crates are frozen at as low a temperature as possible, and stored for periods of up to six months at approximately 15 deg. F. As far as possible, however, they are shipped by the first available boat, in which the prevailing temperatures are of the order of 13 deg. to 16 deg. F. The duration of the storage in Great Britain, where the temperatures of storage vary from 16 deg. to 20 deg. F., naturally depends on the demand, but it may be as great as four months.

Inquiries showed that yellowing of the fat might occur at any link in the chain of storage and transport, and emphasized the importance of the following facts, viz.:—(*a*) the treatment of the carcasses during the pre-freezing period; and (*b*) the temperature and duration of the storage in the frozen condition.

3. Experiments in Storage.

Experiments were planned to enable a study of the above factors to be made. The studies were made on English wild rabbits, but it is improbable that the fat of the English differs materially from that of the Australian variety.

In order to study the effect of factor (*a*), batches of rabbits were frozen immediately after slaughter, and comparable batches were stored, prior to freezing, for 24 hours at 50 deg. F. and 20 hours at 68 deg. F. Rabbits subjected to both treatments were frozen and stored for periods up to twelve months at temperatures of 23 deg. F., 13 deg. F., and 0 deg. F. Commercial conditions were similated by packing the carcasses in small wooden crates, but uniform conditions were maintained in each by exposing the abdominal fat by means of small wooden skewers.

In an account of this nature it is unnecessary to elaborate the statistical and chemical methods employed to measure the rate of onset and intensity of the yellowing of the fat.

(*a*) *Effect of Pre-freezing Treatment.*—The effects of different treatments during the pre-freezing periods were not apparent, of course, until an appreciable period of storage in the frozen condition had elapsed, when it was found that at the three temperatures of storage the onset of yellowness in rabbits which had been frozen immediately after slaughter was greatly delayed. For instance, when the carcasses were stored at 23 deg. F., the time taken to attain a given degree of yellowness was usually about one month longer in the case of carcasses without pre-freezing storage. It is certain that, within limits, the rapidity of onset of the yellowness, and, to some extent, the rate of its subsequent development during storage in the frozen condition, is dependent upon the duration and temperature of storage in the pre-freezing period.

(*b*) *Effects of Temperature and Duration of Storage in the Frozen Condition.*—Table II. shows the time necessary at each temperature of storage, to produce a sufficient intensity of yellowness in the abdominal fat to affect the market value of the carcasses. (Canary to deep-yellow colour.)

TABLE II.

Times for Production of Sufficient Yellowness to Affect Market Value.

Temperature of Storage.	Minimum Duration of Storage (Months).	
	No Pre-freezing Storage.	Pre-freezing Storage.
° F.		
23	2 to 3	1 to 2
13	4 to 5	3 to 4
0	9	8 to 9

Differences in the chemical composition of the fresh fat tend to influence the rate of onset of yellowness, and, although Table II. is compiled from data obtained during two seasons, a slight divergence from the above values is to be expected from year to year. In commercial practice, the intensity of the yellowness at the times and temperatures stated above will approximate to the "critical" tint, but, since every precaution was taken in these experiments to ensure maximum exposure of the abdominal fat in commercial conditions, the average affected area in each carcass will not be so extensive.

After an initial latent period, in general, the intensity and degree of penetration of the yellowness of the superficial fat were approximately proportional to the duration of the storage at each of the three temperatures employed in these experiments. When the period of storage at 23 deg. and 13 deg. F. extended beyond five to seven months, this simple relationship did not obtain, for the rate of yellowing was greatly decreased. This fact may be accounted for by the reduced concentration of the precursor of the "yellow fraction" and by the onset of intense rancidity. At 23 deg. F., fungal and bacterial attack on the fat is an additional factor.

The higher the temperature of storage in the frozen condition the greater is the rate of yellowing, and consequently the deeper the colour after fixed periods of storage. The co-efficient of the rate of yellowing for a rise of 10 deg. C. has been calculated to be between 2.5 and 2.8.

That yellowing is retarded by storage at very low temperatures was amply demonstrated by the results of the experiments carried out at 0 deg. F. Even after the carcasses had been stored for eight months, yellowness was not sufficiently advanced to affect the market value of the carcasses.

Concurrent changes in the fat leading to intense rancidity proceeded independently of the yellowing. Not only did the iodine values of the superficial fat tend to decrease rapidly, but strongly positive reactions were obtained in the Kreis-Kerr test after storage for one to two months at 23 deg. F., and two to four months at 13 deg. F. It was difficult to determine when the production of the acrid odour associated with the advanced rancidity became sufficiently intense to taint the surrounding flesh, but probably the duration of the storage necessary to produce such a condition was approximately twice the above values.

4. Cause and Nature of the Yellowness.

The fatty tissues of the rabbit are always perfectly white,* and even at temperatures as low as 14 deg. F. they are relatively soft. The fat extracted from these tissues is highly unsaturated (iodine value 119 to 179), and the capacity of thin films to absorb relatively large volumes of oxygen and to form moderately tenacious skins classes the fat as a "semi-drying" oil. Analysis of a typical sample of fresh fat showed than linoleic acid formed about 50 per cent. of the mixed fatty acids.

The readiness of exposed fat to absorb oxygen immediately suggested that atmospheric oxidation was not only the cause of the oxidative rancidity, but also of the yellowness. Amongst other experiments, storage in an atmosphere of nitrogen verified this hypothesis. The fatty tissues of rabbits were stored in pure nitrogen for periods up to one year at temperatures of 23 deg. and 13 deg. F. In every case, the tissues remained perfectly white, but controls stored in oxygen developed the usual superficial yellowness. When air replaced nitrogen, yellowness began to develop rapidly.

Although it is probable that yellowness is a special case of rancidity, its occurrence is not general in all highly unsaturated fats and oils. A similar intense yellowness frequently occurs in the superficial oil of fish in cold storage, and, to a smaller extent, in the fat of pork and "aged" linseed oil, but it will not take place in such a highly unsaturated fat as poppy seed oil. It was impossible to produce appreciable yellowness in freshly extracted rabbit fat, either by "blowing" with oxygen or by exposure of thin films to the atmosphere for long periods at temperatures below 32 deg. F. Since simple oxidation of the extracted fat was ineffective in producing the yellowness, it seemed probable that the tissues contained a specific oxidase capable of catalysing the reaction. Such an oxidase, which naturally was destroyed in the process of the extraction of the fat from the tissues, was found to be present in the fatty tissues of the rabbit, and, under

* Except in a few rabbits which have absorbed xanthophyll from their food. This type of yellowness is a character inherited according to Mendelian principles.

certain conditions, a concentrated aqueous extract of the oxidase produced yellowness in extracted rabbit fat. In addition to this enzyme, hæmoglobin and water were found to be effective catalysts.

The yellow fraction of the fat had its origin in the oxidation of the linoleate glycerides. Methods elaborated for the isolation and purification of the "yellow fraction" of the fatty acids showed that it resembled an oxidized acid containing 18 carbon atoms, and that the pigment existed *in situ* as an unsaturated ketonic compound, the chemical constitution of which has not yet been elucidated.

5. Preventive Measures.

In the search for suitable methods for the prevention of yellowing, the guiding principle was the exclusion of air from the fatty tissues. Storage in nitrogen inhibited the yellowing, but it is a method which has, as yet, little commercial interest. A large number of supposed impermeable coatings were applied to the fatty tissues, but for various reasons none was successful.

The fact that where the internal wall of the abdomen (the "belly flap") had accidentally been placed and remained in contact with the fat surrounding the kidneys no yellowing developed indicated a possible solution. To secure this always it would be necessary to separate the skin from the muscles of the belly floor and then to fold over the flaps so that they covered the kidney fat. With the muscle thus rendered more pliable, the abdominal wall could always be made to adhere effectively to the abdominal fatty tissues, except in the case of very fat rabbits, when it was difficult to cover the ends ventral to the kidneys. Experiments showed that, when rabbits were prepared in this way, the superficial fat developed no yellowness or odour, even after storage for six months under conditions which would normally lead to intense yellowness.

6. Conclusions.

The nature of the demand in Great Britain for imported rabbits is such that the bulk of the rabbits caught in Australia during January, February, March, and April cannot be placed on the market before August or September. It seems inevitable that, with the existing methods of storage, the fat of such rabbits must undergo a considerable amount of yellowing and rancidity, but it is possible that the method described above of covering the abdominal fat by the muscular wall of the gut may minimize this deterioration, which, of course, is likely to be aggravated by the higher pre-freezing temperatures prevailing during those months. The only alternatives appear to be a combination of a shorter period between the death and the freezing of the rabbits, storage at lower temperatures than those hitherto employed, and, if possible, shorter periods of cold storage.

On the basis of the data given in Table II. it is suggested that the temperatures of storage should not exceed 7 deg. F. While it may be possible to employ much lower temperatures for storage in Australia and Great Britain, it would seem difficult to obtain them during the ocean transport, since the rabbits must be stowed in the same holds as other frozen produce which do not require such low temperatures for their storage.

Since blood (hæmoglobin) is an effective catalyst in the production of the yellowing, it is important to remove all traces of blood from the gut cavity before the rabbits are packed.

The Use of Acetaldehyde in the Storage of Fruit.

By S. A. Trout, M.Sc., and R. G. Tomkins, B.A., Ph.D.

Mr. Trout is a research student under the provisions of the Science and Industry Endowment Act. He left Australia in August, 1928, and was kindly accommodated at the Low Temperature Research Station of the British Food Investigation Board. The article that follows constitutes an account of a portion of his investigations. Dr. Tomkins is an officer of the British Board.—Ed.

1. Introduction.

Wastage in stored fruit is due largely to rotting, caused by the growth of mould fungi, which are well known to be retarded or inhibited in their development by the presence in the atmosphere of small quantities of certain volatile substances. Is it then possible to use these substances to prevent the decay of fruit in storage?

If present in sufficiently high concentrations, many volatile substances would certainly prevent decay. They might, however, by the very reason of their property of reducing mould growth, also injure the fruit, a wholly undesirable result. If, on the other hand, a substance could be found which prevents mould growth but does not injure the fruit, it would perhaps provide the basis of a practical method for reducing the losses in stored fruit.

Experiments described below suggest that acetaldehyde is a substance which, when present in a concentration sufficient to prevent mould growth, does not injure the fruit.

The possibility of using acetaldehyde as a means of preventing mould growth became apparent in experiments on the effect of acetaldehyde on the metabolism of the fruit[1]. A full account of these experiments will appear later. It is sufficient to mention here that acetaldehyde is known to occur as an intermediate product of the plant's metabolism, and that it is oxidized by plant tissues. This is a strong argument in favour of its use in preference to the use of other substances which might accmulate within the tissues and not be removed by any metabolic process.

The direct effect of acetaldehyde on mould growth is also being studied[2]. The present experiments may be considered subsidiary to the two main investigations which are being undertaken independently by the two authors.

2. Methods.

Fruit is stored in large glass desiccators. Air, which is first drawn through towers of glass beads down which acetaldehyde solutions pass, is led through the desiccators at the rate of 5 litres per hour. The concentration of the aldehyde vapour contained in the air, ascertained by absorbing a known volume of aldehyde air in a bisulphite solution, is approximately two-fifths of that of the solution in the tower.

Fruit has been stored at different constant temperatures and in atmospheric concentrations of acetaldehyde ranging from 1/200 to

(1) The action of acetaldehyde upon fruit, S. A. Trout, British Food Investigation Board, Annual Report, 1929, p. 59.
(2) The effect of acetaldehyde on the growth of moulds, R. G. Tomkins, British Food Investigation Board, Annual Report, 1929, p. 57.

1/1,000 by volume. At times, sound fruit has been used; at others, the fruit has been wounded; while at still others, wounded fruit inoculated with rot-producing fungi has been used.

3. Storage Experiments.

Oranges.

Sound Oranges.—Three comparable samples were stored at 10 deg. C., one in air, one in air drawn over 1/100 acetaldehyde, and the other in air drawn over 1/200 acetaldehyde, with the following result:—

(1) In air, all oranges mouldy after five months.

(2) In air from 1/100 acetaldehyde (atmospheric concentration 1/250), all sound after seven months.

(3) In air from 1/200 solution acetaldehyde (atmospheric concentration 1/500).

Oranges from (2) and (3) when removed from aldehyde remained sound for another month.

Wounded Oranges.—Wounded oranges were stored at 10 deg. C.:—

In air, after 30 days, all were infected.

In atmospheric concentrations of acetaldehyde of 1/250 and 1/500, all were sound after 60 days.

Wounded Inoculated Oranges.—The wastage in oranges which were wounded and inoculated and stored at 10 deg. C., some in air and some in "acetaldehyde air," is tabulated below. The figures indicate the total number out of 20 which were mouldy:—

——	Treatment.	Concentration of Acetaldehyde in Air.	Number of Days. 14	28	35	57	72
Inoculated with *P. dig.*	No acetaldehyde ..	0	19				
	Acetaldehyde ..	1/250	0	1	1	2	3
Inoculated with *P. ital.*	No acetaldehyde ..	0	19				
	Acetaldehyde ..	1/250	0	1	1	3	5
Not inoculated ..	No acetaldehyde ..	0	0	0	0	0	1
	Acetaldehyde ..	1/250	0	0	0	0	0

The method of inoculation was to wound twelve times oranges which had previously been sterilized with a solution of mercuric chloride in methylated spirit, and then immerse in a spore suspension.

The experiment shows that, when acetaldehyde is present, the mould can be largely prevented from attacking the orange.

What is not recorded in the table is—

(i) That on removing the oranges from 1/250 acetaldehyde, they were quickly rotted.

(ii) That 1/250 acetaldehyde caused a breakdown of the skin of some of the oranges.

It is therefore necessary to decide—

(1) How control of rotting varies with concentration of acetaldehyde.

(2) The concentrations of acetaldehyde which cause a browning of the skin.

Concentration of Acetaldehyde Vapour and Attack by P. digitatum.—Wounded inoculated oranges were stored at 20 deg. C. in air drawn over water and acetaldehyde of strengths 1/100, 1/200, 1/500, and the wastage in samples of twenty was—

Solution Strength.	Concentration in Air.	10 Days.	18 Days.	24 Days.	32 Days.
Water	..	15	16	18	
1/500	1/1250	14	16		
1/200	1/500	6	9	11	11
1/100	1/250	0	0	0	0

Mould attack is seen to be held very much in check by atmospheric concentrations of 1/500 acetaldehyde, and completely inhibited by 1/250 acetaldehyde.

Unfortunately, at these concentrations there is a noticeable browning of the fruit. After 18 days at atmospheric concentrations of 1/500 acetaldehyde, 70 per cent. (14) showed skin browning, while at 1/100 all oranges had brown discolorations. Browning is more noticeable at wounds than elsewhere, and wounded oranges are far more susceptible to acetaldehyde injury than sound fruit. At atmospheric concentrations of 1/1,250 there was no marked browning.

Discussion.—On the results of the above trials, can acetaldehyde be recommended for the prevention of green mould in citrus? The evidence is certainly too meagre to decide this question finally. Provided the concentration of acetaldehyde is maintained, and also the temperature is low, it seems that this method is effective. At higher temperatures, the concentration needed to check growth appears to be greater than at lower temperatures, a result in agreement with the effect of a given concentration on a mould growing in pure culture. Unfortunately, the higher concentration of acetaldehyde appears to cause damage to the fruit.

The conditions of the experiment were very exacting, and when one compares the above results with those obtained for the effectiveness of borax in controlling wastage of oranges which were first inoculated and wounded, and considers how effective borax may be under commercial conditions, it would seem that there is good reason to hope that acetaldehyde would also be effective under commercial conditions.

Soft Fruits.

Grapes. Continuous Acetaldehyde Storage.

Grapes have been stored in an atmosphere containing acetaldehyde with very promising results.

Grapes were wounded by pricking with a needle. Half were stored in the air, and half in air led over 1/400 acetaldehyde solution. The temperature of storage was 25 deg. C.

In air, all grapes were mouldy after three days. In atmospheric concentration of 1/1,000 acetaldehyde, there was no infection for 21 days, when mould appeared on stalk.

Grapes. Storage after Short-period Exposures.

Wounded grapes were exposed at 25 deg. C. to 1/250 acetaldehyde (air concentration) for 24, 48, 96 hours respectively, and then stored in air and examined after 8 and 17 days.

—	Eight Days.	Seventeen Days.
Control	Slimy mass	
24 hours' exposure	Slight mould	Mouldy
48 hours' exposure	All sound	Mouldy
96 hours' exposure	All sound, slight taste ..	All sound

The experiment was repeated at 1 deg. C., and the fruit exposed to 1/250 acetaldehyde (air concentration) for 72 hours, 144 hours, and 288 hours.

After eighteen days, the condition was—

Controls	Mouldy.
72 hours' exposure	Good, and taste normal.
144 hours' exposure	Good, but taste of aldehyde.
288 hours' exposure	Good, but taste of aldehyde.

Eighteen days later, no mould had developed on those grapes exposed to aldehyde.

Strawberries and Raspberries.

Strawberries and raspberries were stored at 5 deg. C. in air and in aldehyde vapour.

Strength of Acetaldehyde Solutions.	Concentration of Acetaldehyde in Air.	Condition of Fruit after Ten Days.
Controls	..	All mouldy
1/1000 acetaldehyde sol. ..	1/2500	80 per cent. mouldy
1/400 acetaldehyde sol. ..	1/1000	All sound, taste normal
1/100 acetaldehyde sol. ..	1/250	No mould, blackening of fruit

The sample from 1/1,000 (air concentration) was taken from the aldehyde air and stored in air. Mould developed after ten days.

Cherries.

Cherries were stored at 5 deg. C., with the following results:—

Concentration of Solutions of Acetaldehyde Used.	Concentration of Acetaldehyde in Air.	Condition of Fruit after Ten Days.
Controls	..	All mouldy
1/1000 sol.	1/2500	80 per cent. good
1/400 sol.	1/1000	78 per cent. good
1/100 sol.	1/250	No mould attack. Fruit black

The storage was not prolonged beyond ten days.

Plums.

Plums have not been stored continuously in acetaldehyde. They have been exposed to acetaldehyde of 1/250 (air concentration) and then stored in air. The percentages of sound plums after 16 and 23 days' storage were—

——	Sixteen Days.	Twenty-three Days.
	%	%
Control	46	..
24 hours' exposure	93	37
48 hours' exposure	93	50
72 hours' exposure	97	80

4. The Advantage of Storage in Acetaldehyde Vapour.

The results of the trials described above clearly demonstrate that fruit stored in the presence of aldehyde remain free from mould attack considerably longer than fruit stored in air. They also show that, though the concentration of acetaldehyde necessary to check mould development may be quite small, yet at somewhat higher concentrations of acetaldehyde, serious damage to the fruit—involving both appearance and taste—may result.

The concentration needed effectively to control mould attack varies both with the variety of fruit and the temperature of storage. Therefore, before use on a commercial scale can be recommended, it will be necessary to know more nearly those concentrations which cause damage to fruit at various temperatures, and also the concentrations for effective control.

Commercial application also demands the perfection of a method of introducing acetaldehyde into the atmosphere and maintaining it there in small, but definite and constant, concentrations. This is a problem for our engineering colleagues.

5. Dipping Treatments.

The maintenance of a given concentration of acetaldehyde in the atmosphere is not a simple task, and it may well be asked if some other mode of application is not equally effective.

It is claimed that increased storage life has followed immersion in formaldehyde solutions. It is also well known that borax and sodium bicarbonate present on the skins of citrus fruit after immersion in solutions of these substances very largely prevent mould attack.

The use of non-volatile substances which remain on the surface of the fruit after a dipping treatment has an obvious advantage over volatile substances, which would quickly disappear from the fruit after removal from the dipping solution. Nevertheless, because of the simplicity of this treatment, and because formaldehyde is said to produce increased storage life, fruit has been dipped in acetaldehyde and its storage life observed.

Experiments conducted on the dipping of wounded and inoculated oranges in solutions of acetaldehyde were, however, unsuccessful. But the times of exposure were long, the concentrations employed high, and

the oranges wounded. Though long exposure to high concentrations should have effected a greater sterilization of the fruit, and hence reduced wastage, it also caused greater injury, especially at the wounds, and this increased the susceptiblity to mould attack. A suitable time of exposure and strength of acetaldehyde may yet be found to give control, and further trials are necessary before the method is finally abandoned.

The Use of Acetaldehyde for the Preservation of Fruit.—Three methods of using acetaldehyde for the purpose of prolonging the storage life of fruit have been explored in a very preliminary way. The method of dipping fruit into solutions was not successful in the case of citrus fruits.

The method of short exposure (one to four days) to air containing certain concentrations has given some measure of success in the storage of grapes.

The third method of continuous exposure to atmospheres containing small concentrations has yielded very promising results in certain instances. Because, however, of the difficulty of finding the most suitable concentration which prevents mould growth without damaging the fruit, and because of the technical difficulties of maintaining the composition of atmospheres, the commercial possibilities should not at the moment be over-estimated.

Should these difficulties be overcome, the cost of the method should not be prohibitive.

For chemical work, 500 grammes of the pure reagent can be obtained for 8s. 9d. This would vaporize to approximately 90 cubic feet, and so for a volume concentration of 1/250 would condition 22,000 cubic feet of air. The leakage in practice would, however, be great, but even with a 10 per cent. efficiency the cost of aldehyde would still be small.

6. Summary.

Fruit stored in atmospheres containing small quantities of acetaldehyde has in certain instances remained in a sound condition considerably longer than fruit stored in air.

Acetaldehyde, therefore, seems to be a volatile substance which might be introduced into fruit stores in sufficient concentrations to check wastage due to mould growth without injuring the fruit.

The range of concentrations controlling mould development without causing damage to the fruit is, however, very limited. Further study is needed to determine the extent to which the use of acetaldehyde can be successfully applied to large scale storage undertakings of the commercial type.

The Occurrence and Distribution of Salinity in a Virgin Mallee Soil.

By J. E. Thomas, B.Sc., B.Agr.Sc., B.V.Sc., Commonwealth Research Station, Merbein.

I. Introduction.

During the progress of a preliminary survey of an area of 30 acres of virgin country intended for the experimental study of the development of salt troubles throughout the period of establishment of a vineyard under the conditions prevailing in the Mildura irrigation district, a remarkable distribution of salt in the soil, both horizontally and vertically, was noted, and the data obtained are of sufficient interest to be worthy of record at the present stage.

The experimental area under investigation is situated at Merbein, 7 miles west of Mildura and 4 miles from the River Murray. The area is commanded by the normal channel system of the Merbein settlement. The preliminary work consisted of the detailed contour, botanical, soil, and salt survey. For these purposes, the field was pegged out at 4 or 5 chain intervals, each point being defined by a permanent numbered peg. The levels, determined at the corners of 1-chain quadrats, were then mapped, and the contour lines drawn at 3-in. intervals. The botanical survey was carried out by Mr. C. Barnard, M.Sc., who mapped the native vegetation in each quadrat and transferred the results to a large scale map. In addition to the vegetation, notes were made of the position of roads and other soil disturbances.

For the salt and soil survey, holes to a depth of 16 feet were bored by means of a post-hole auger at each numbered peg, which, it was considered, might possibly lie within the future experimental area. Similar holes were bored at the centre of each 5-chain quadrat. The samples from these 16-ft. holes were taken at 6-in. intervals. In addition to these, further borings were made at intermediate points to the "blue clay" layer, which was usually met with at about 8 feet. The samples from these latter holes were taken at intervals of 1 foot. In the field, a log of each soil profile was kept. In the laboratory, the percentages of lime nodules and of gypsum crystals retained on the 2 m.m. sieve were recorded. Soil-moisture determinations on the fresh samples were also made. The chloride content—expressed as Cl as a percentage of the dry soil—was obtained by the titrating of the supernatant fluid from a 1 to 5 soil water mixture shaken for one hour. To obtain clear extracts from the deeper soils, candle filtration was found necessary. Later, however, by adopting the method of electrometric titration (Best), a considerable saving in time was effected. Total soluble salts were determined by means of a conductivity bridge, the resistances being plotted against the soluble salt content of check samples. The points obtained fell close to a smooth curve, and reasonably accurate results were obtained provided certain precautions were adopted. Other methods of soil examination were those recommended by the C.S.I.R. Division of Soils (Prescott and Piper).

After completing this first general soil and salt survey, further samples were taken to depths of 6 feet at intervals of 22 feet along certain selected reference planes, and on these samples the chloride content was determined.

2. Soil Type.

The soil profile of the area under investigation is derived from a wind-blown calcareous loam or sand overlying a heavy clay of deltaic or lacustrine origin. The mature profile is developed within the upper zone, and shows a differentiation into horizons including a sandy surface and horizons of calcium carbonate rubble and of gypsum.

A typical section shows a surface layer consisting of a calcareous sand or sandy loam. At about 2 feet to 2 ft. 6 in. there is the maximum concentration of nodular limestone (rubble). Underneath this, there is a red clay which contains gypsum crystals, and is usually quite free from rubble. This layer, in turn, rests on a blue clay, which, in mechanical composition, is very similar to the heavier recent river alluvials. This blue clay gradually becomes lighter in texture, and merges into an iron-stained sand, which in turn gives place to a clear white drift sand of indefinite depth at or about 60 feet. This "drift" is utilized in the drainage schemes of the district, the drainage waters from the underground tile drains being discharged into shafts, which are sunk into this drift sand. So far, this method of disposal of drainage waters has been generally satisfactory.

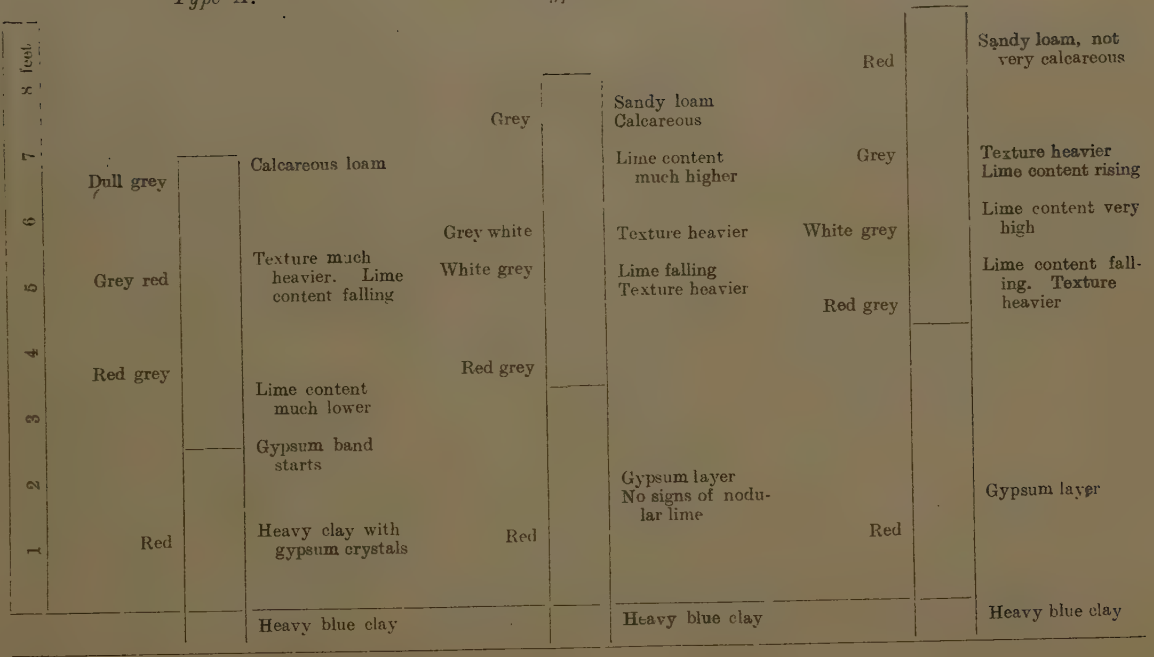
The calcium carbonate content of the top few feet is in the neighbourhood of 20 per cent., and there is reason to believe that part, at least, of the lime present is of aeolian origin. It is probable that the peak concentration of lime at a depth of 24-30 inches is associated with the depth of leaching in this relatively permeable soil.

Three soil types were defined and mapped from the data of the bores of the first general survey, the later intensive survey, and further additional definitive bores. The typing of soils adopted is quite provisional pending the completion of a district soil survey, although there is reason to believe that the types defined can be fitted in as types or sub-types in such a systematic survey.

Diagrammatic profiles of the three types are illustrated below; these suggest the three soil types as being closely related and defined essentially by the depth of aeolian layer above the older alluvial deposits.

The mean depths of this layer from the surface were, in the case of the A type soils, 7.1 feet; in type B, 8.6 feet; and in type C, 9.0 feet. The depth from the surface to a red clay containing gypsum crystals varied from 4.8 feet in the case of the A soils to 6.4 feet in the case of the B and C soils. The percentage of gypsum crystals retained on the sieve for the individual samples varied from 0.1 to 5.0 per cent., with an average of about 0.3 per cent. The vertical distribution of sulphate in a type B soil is shown below (Table 1). A calcareous layer overlies the gypsum horizon; it is brown in colour, and in texture varies, in the case of the B soils, from a sand to a sandy loam. The total concentration of calcium carbonate in the fine earth was found to be related to the amount of limestone nodules retained on the sieve. The percentage of rubble in the field samples varied between the limits 1 to 30 per cent., with a possible mean of about 3 per cent. The line of peak concentration of calcium carbonate, the beginning of the gypsum and blue clay layers, are shown in Fig. 3. The concentration of calcium carbonate diminished very rapidly both above and below the line of maximum concentration, and it was extremely rare to find any rubble present in the gypsum layer. Table I. indicates that the percentage of lime in the fine earth is appreciable.

Soil Profiles.



SOIL PROFILE TO SIXTEEN FEET.

Type B.

Grey	1	Calcareous sand
	2	Lime content increasing
	3	Texture somewhat heavier
Grey white	4	Maximum lime content
Red grey	5	Lime content falling Texture heavier
Red	—6—	Heavy gypsum layer
	7	No nodular lime present
	8	
		Stiff blue clay begins
	9	
Blue	10	
	11	
	12	Clay becoming iron-stained
Blue with red streaks	13	
Blue—occasional yellow streaks	14	Occasional sandy pockets present
	15	Gypsum band
	16 feet	Blue clay
		To white drift sand at 50–60 ft.

TABLE 1.

Distribution of Calcium Carbonate and Gypsum in Soil Type B.

Depth. Feet.	$CaCO_3$ Per cent.	$CaSO_4.2H_2O$ Per cent.
0–1	12.0	0.13
1–2	20.7	0.18
2–3	23.7	0.26
3–4	21.9	0.45
4–5	18.4	0.73
5–6	15.6	2.21
6–7	11.0	1.06
7–8	8.4	0.51

The rubble present varied in size from a grain of shot to a marble, and, in section, often showed silicious areas. An analysis of some typical nodules was as follows:—

Acid (HCl) insoluble	22.2
CaO	32.1
MgO	6.2
CO_2	31.3

corresponding to 57.1 per cent. of calcium carbonate and 13.1 per cent. of magnesium carbonate.

The surface horizon of the type C soils was redder than that of the type B soils and was much less calcareous; this layer is classed texturally as a sand, and extends to a greater depth than in the B soils. Type A soils have some features in common with the type 6 Renmark soils, but they are considerably lighter in texture, and rest, in this case, on a blue clay, whereas at Renmark the underlying stratum is sandy.

Mechanical analyses of the three soil types are set out below:—

TABLE 2.

Mechanical Analyses of Soil Types.

	Type A.		Type B.		Type C.		Blue Clay 9′-10′.
	0–2′.	2′–5′.	0–2′.	2′–5′.	0–2′.	2′–5′.	
	%	%	%	%	%	%	%
Coarse sand ..	22·8	12·5	28·3	19·8	30·3	23·5	12·8
Fine sand	33·0	25·8	32·8	27·9	37·6	29·3	26·5
Silt	5·5	5·7	4·8	3·7	6·6	3·7	9·6
Clay	15·9	33·4	10·1	17·3	12·6	13·2	44·5
Loss on acid treatment	17·6	14·2	19·0	23·9	9·5	24·4	1·3
Moisture	4·1	9·3	4·2	7·5	4·1	6·3	6·4
Calcium carbonate ..	17·0	5·7	17·3	22·1	8·2	22·6	..

3. Salt Survey.

The data obtained during the salt survey have been plotted both on horizontal and vertical sections of the area, and disclose a remarkably patchy distribution of the salt. Of the several diagrams prepared, it will probably suffice to illustrate one typical horizontal section showing the distribution of salt over the whole area to a depth of 3 feet (Fig. 1)‡, and three parallel vertical sections showing the distribution to a depth of 6 feet (Fig. 2).

The salinity has been expressed in terms of the chlorine calculated to 100,000 parts of the dry soil. Similar results would, no doubt, be obtainable for total salts, but owing to the presence of gypsum it has been considered sufficient to allow the chloride concentration to typify the distribution of salinity over the area in question.

A complete analysis of the water soluble salts present in one particular profile of soil type B is given below:—

TABLE 3.

Water Soluble Salts Present in Soil Profile.

Depth of Sample.	Ca.	Mg.	Na.	K.	HCO_3.	Cl.	Total Soluble Salts.*	Total SO_4.†
ft.	%	%	%	%	%	%	%	%
0–1	·012	·005	·059	·005	·038	·095	·197	.072
1–2	·005	·005	·138	·004	·041	·171	·436	·103
2–3	·006	·006	·163	·005	·056	·210	·786	.144
3–4	·006	·007	·213	·006	·053	·234	..	.252
4–5	·010	·011	·204	·007	·032	·214	..	.410
5–6	·057	·013	·171	·006	·026	·209	..	.235
6–7	·028	·011	·166	·007	·032	·219	..	.592
7–8	·006	·008	·203	·006	·050	·223	..	.286

* Determined conductimetrically. † Determined in a 2 per cent. HCl extract.
‡ See Plate 3 *et seq.* facing page 54.

The sodium salts, and particularly sodium chloride, constitute the bulk of the salts present. The composition of the water soluble salts is similar in many respects to those recorded on samples from Renmark (Taylor and England, p. 33). The averaged values for chlorides for each soil type are shown in Fig. 4, and for the whole field are given below. It will be noted that the Cl content regularly increases to a maximum of 0.334 per cent. at 13 feet:—

TABLE 4.

Mean Values for Chlorides for whole Field.

Depth. Feet.	Cl. Per cent.	Depth. Feet.	Cl. Per cent.
0–1	0.029	8–9	0.182
1–2	0.080	9–10	0.240
2–3	0.117	10–11	0.255
3–4	0.134	11–12	0.267
4–5	0.140	12–13	0.334
5–6	0.159	13–14	0.316
6–7	0.171	14–15	0.310
7–8	0.178	15–16	0.278

	Per cent.
Mean total salts in top 3 feet	0.250
Mean chlorides in top 3 feet (as NaCl)	0.120
Mean chlorides in clay layer at 7.9 feet (as NaCl)	0.196
Mean chlorides in clay layer below 7.9 feet (as NaCl)	0.450

4. Soil Reaction.

In a number of instances, the reaction of the soil samples has been determined, and one important soil section has been completed, and is illustrated in Fig. 5. In view of the high alkalinity of these soils and high temperatures prevailing in the Merbein laboratory, the pH values have been revised by means of the antimony oxide electrode, and the data are probably very close to the correct values for this particular soil type.

5. Dicussion.

CORRELATIONS.

(*a*) *Soil and Vegetation.*

Mr. C. Barnard, in his vegetation survey, has recognized four well-marked communities, described as follows:—

(1) *Kochia pyramidata Kochia sedifolia* association (Bluebush association).

(2) *Eucalyptus oleosa–Eu. dumosa Eu.–gracilis* association (Mallee association).

(3) *Myoporum platycarpum–Heterodendron oleifolium* association (Sandalwood association).

(4) *Casuarina lepidophloia* consociation (Belar association).

The boundaries of these associations, together with those of the soil types, are indicated in Fig. 6. Surface contours are illustrated in Fig. 7. The close association of the bluebush with the soil type A is to be observed, and the distribution of the Mallee communities on the

slopes surrounding the gentle depression characteristic of the area of type A is also to be noted. The Mallee association is essentially associated with the slopes of type B soil, leaving the sandalwood community dominating the long ridge of this type, and including the small areas of type C. The principal community of belar appears to be associated with a relatively deep soil intermediate between the types B and C.

(*b*) *Soil Type and Soil Salinity.*

The salinity figures for each soil type, averaged from the results of the first survey, have already been discussed (Fig. 4). The lower surface concentration of salinity in soil type A is to be associated with the contours, a feature well brought out in Fig. 2. During the very occasional heavy rains water will accumulate in a depression such as is indicated in this area, resulting in a movement of salt downwards and outwards from the area. In the B soils, the salinity varies irregularly, and there are highly saline areas quite close to the surface. The mean concentration of chlorides, expressed as Cl in the top 3 feet for the A type soil was 0.060 per cent.; for B, 0.095 per cent.; and for C, 0.074 per cent. These figures are high when compared with the corresponding figures for local irrigated soils, and there is little doubt that there must be a very considerable loss by leaching in virgin soils after the first irrigations. The problems of saline soils are usually due to a dangerous concentration of soluble salts within a comparatively restricted zone.

Apart from a general association of the Mallee communities with areas of high salinity and the natural association of the bluebush with the low-lying areas of low salinity, there appear to be no general relationships between the vegetation and soil salinities. In all probability, the four principal associations are relatively tolerant of soil salinity.

(*c*) *Climatic Considerations.*

The most important factors likely to control the salt distribution in a virgin area such as the one selected for observation are rainfall, evaporation, and soil permeability. The rainfall is mainly of the winter type, and the mean annual rainfall probably lies between that of Wentworth, 11.4 inches, and that of Mildura, 10.5 inches. During the period 1924-29 the mean annual rainfall was 8.47 inches, and the May-September total 4.12 inches.

An additional factor to be considered when estimating rainfall effectivity is the drying power of the atmosphere, which is usually measured in terms of water loss from a free water surface. Owing to high temperatures, low rainfall, low relative humidities, and frequent drying winds, the Merbein evaporation averages 70.1 inches annually, rising from a minimum of 1.7 inches in June to a maximum of 10.6 inches in January. A further factor to be considered is the depth of penetration of the rainfall, which is controlled both by the type of rainfall and the permeability of the soil. An examination of the ten years' records at this station disclosed that daily falls of rain of less than 0.15 inches comprised 40 per cent. of the total—0.15–0.40 inches 22 per cent., and over 0.40 inches 8 per cent. This high proportion of small falls, coupled with a high rate of evaporation, must very considerably reduce the efficiency of the rainfall as a leaching agent, but there is one compensating feature in the permeable nature of the soil.

There is usually little run-off, and moisture is able to penetrate relatively rapidly on the light Mallee soils. The conditions are such that no streams originate, and it would be expected that there would be very little, if any, leaching of soil soluble salts except to a relatively shallow depth.

6. References.

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7. Summary.

The salt content of an area of virgin Mallee country in the Merbein district of Northern Victoria has been studied by means of intensive survey, and a remarkably variable distribution of salinity, both horizontally and vertically, has been observed. This distribution is to be correlated in various degrees with relief, soil types, and vegetation associations. Selected data typifying the conditions observed are presented. It is further proposed to study during the next few years the redistribution of the salt under various conditions of irrigation practice.

8. Acknowledgments.

The writer wishes to thank Mr. A. V. Lyon, Officer-in-Charge, Commonwealth Research Station, Merbein, for much valuable assistance; Professor J. A. Prescott, Chief of the Commonwealth Division of Soils, for much helpful criticism and advice, both during the survey and in presenting the data; and Messrs. J. S. Hosking and R. J. Best, of the Waite Research Institute, Adelaide, for the revision of the soil reaction values.

Mineragraphic Investigations: Their Importance to the Australian Mining Industry.

By F. L. Stillwell, D.Sc.

1. Introduction.

It is well known that a crude ore has to undergo a course of preliminary treatment, often quite complicated, before the final concentrates can be economically treated in the smelting furnace and before the metal values can thus be extracted. The object of this preliminary ore-dressing treatment is naturally to separate out to as great an extent as possible, and with due attention to cost, the particular mineral constituents that carry the metal values desired by the smelter.

Quite a number of methods have been devised in the past whereby this mechanical separation of the individual constituents of an ore may be more or less economically made. In all these methods, whether they involve concentrating-tables, jigs, settlers, &c., or whether they consist of the more recently developed flotation processes, use is made of differences of physical properties in the constituent minerals of the ore. As complete a knowledge as possible of these individual constituents, their chemical nature, their grain size, and their mutual relationships, is thus obviously of outstanding importance to the dressing of ores, if the necessary preliminary treatment is to be carried out in the most economical way. In the past, some of this knowledge has been imperfect and some quite unobtainable, simply by reason of the lack of an effective method of obtaining it. Accordingly, overmuch reliance has had to be placed on chemical analyses and assays, which at best convey little information regarding the mineral composition of an ore or concentrate, and none at all regarding the manner of the mineral association.

Within the last two decades a striking advance has been made, particularly in the United States of America, by the study of ores in reflected light, a subject which is called mineragraphy. By such a study, the individual minerals of an ore may be somewhat rapidly and precisely determined, and from the point of view of the mining industry, an account of it thus becomes of interest. It may also be remarked that it gives results of economic value, not only in connexion with ore dressing, but in other ways, which will be more fully discussed later.

2. Mineragraphic Technique.

For almost a century past, use has been made of the microscope for the study of thin sections of rocks, and the extensive branches of knowledge in the fields of petrology and mineralogy have resulted. Most of the constituent minerals in rocks, however, are transparent, and consequently are readily examined under the microscope by ordinary transmitted light. With ores, on the other hand, the constituent minerals are almost invariably opaque, and this condition applies in

particular to the all-important, from an economic point of view, group of sulphides. The reflecting microscope as developed for metals and alloys has, therefore, been brought into use. At first, progress was slow, and, in fact, many years followed the earliest efforts in this direction before the significance and value of the field of investigation was realized. Gradually, however, a mass of information has been accumulated as to the appearance and other physical properties of the various ore minerals, so that the modern metallurgist and geologist have now a potent means whereby to determine the particular mixture of minerals which constitutes any particular ore with which they may be dealing.

The necessary apparatus is comparatively simple, consisting in the main of an ordinary microscope fitted with a vertical illuminating device. By means of this device, rays of light entering the side of the microscope tube from a special illuminating source are deflected down the tube to a highly polished surface of ore, from which they are again reflected to the eye of the observer. There they yield a brightly illuminated field, in which the constituent minerals can be studied under a wide range of magnifications. For ordinary work, the magnification is seldom greater than 400 diameters, and generally it is much less, but, if necessary, the illumination is quite satisfactory with much higher magnifications, and even with those obtainable only by use of oil-immersion objectives.

(*a*) *Preparation of Specimen.*—The initial step in the examination of a specimen is the preparation of a highly polished surface. A finely ground surface is first obtained by grinding with different grades of carborundum, in the same way as rock chips are ground prior to the preparation of a rock section. If the particles are too small for handling, as in the case of concentrates, tailings, and other mill products, the material is mounted by mixing with a cement, such as molten sealing wax contained in a convenient mould. On solidifying, the mass is ground, and treated in the same way as lump ore. The polish is then given by one of two methods.

The more common method is comparatively rapid, and consists in holding the specimen in contact with a metal disc over which fine linen has been tightly stretched, and which rotates from 800 to 1,000 revolutions per minute. The linen is moistened with emulsions of polishing powders, and the successive application to two revolving laps, one for emery and one for chromic oxide (for the final polish) is generally sufficient. The time required for polishing depends on the variety of mineral. In many cases, the polish develops quickly, but some minerals, for example pyrite, are difficult to polish, and require an application of several minutes.

The second method of polishing is exceedingly slow, and, being a much newer method, has not yet been brought into general use. In this method[1] a disc of soft metal, such as lead or copper, is used without linen, revolving at the comparatively slow rate of about 60 revolutions per minute. The discs are radially or concentrically grooved, and the grooves are filled with the polishing powder mixed with oil. The specimen is held in contact with the metal disc by a mechanical holder, which rotates at about 200 revolutions per minute. The polish develops slowly over a period of a few hours, but, in the

(1) *Economic Geology* XXIII.: pp. 292–322, 1928.

absence of the linen, a surface is obtained which is practically optically true, and yields perfect contacts between hard and soft minerals. The use of linen-covered laps produces a certain amount of relief between materials of different hardness, and this, while useful in some cases, is a serious defect in others. Incidentally, if the linen is replaced by a softer cloth, such as flannel or felt, the amount of relief in the section is greatly increased.

(*b*) *Methods of Examination.*—The identification of the mineral species is carried out by studying their colour, their hardness, the effect of polarized light, and their chemical behaviour to certain standard reagents. A few minerals, like gold, have very distinct colours, and are readily recognized almost at a glance. The majority, however, appear in reflected light to be white or nearly white, and the colour differences are delicate shades of pinkish, greyish, brownish, or bluish white. Nevertheless, the delicate tints are constant with the same standard of comparison, and are often useful in discerning the constituent minerals in a heterogeneous mixture.

Hardness is another important determination. Relative differences in this property can be detected by the observation of the contact of two minerals when light lines, similar in appearance to the Becke line as used in refractive index determinations of transparent materials, are observed. This line moves from the harder to the softer mineral upon raising the tube of the microscope. The hardness of materials is commonly described by reference to different orders in Moh's scale of hardness. The microscopic observations, however, have been found to be capable of distinguishing more delicate degrees of hardness than is indicated in Moh's scale. As a result, a scale of hardness for the ore minerals has been brought into use, the scale being determined quantitatively by drawing a weighted diamond point across the polished surface[2]. The hardness of the mineral is then referred to a scale determined by the varying weights required to produce a scratch of a certain depth in the mineral.

The passage of the rays of light through a nicol prism before reflection to the polished surface, and then after reflection through a second prism known as the analyser, often gives useful criteria for distinguishing opaque minerals. The observations are somewhat analogous to the study of the effect of polarized light on transparent minerals to distinguish between isotropic and anisotropic varieties, and in some cases afford a ready means of distinction between two opaque minerals, such as pyrite and marcasite, which are similar in most properties except crystalline form.

The most useful method of identification is that of etching, which is sometimes essential to emphasize the difference between neighbouring minerals otherwise closely similar in colour and hardness. When it is desired to apply a chemical reagent to a mineral of microscopic dimensions, a loop of platinum wire is used, similar to that employed for borax beads in blowpipe tests. As much reagent as can be held in a fine loop is applied to the mineral while the latter remains in view under a low-power objective. The reagents most generally used are nitric acid, hydrochloric acid, potassium cyanide, ferric chloride, mercuric chloride, and caustic potash. According to the positive or negative reaction with these reagents, an unknown mineral can be identified, or,

(2) *Economic Geology* XX.: pp. 531 553, 1925.

at least, reduced to a limited number of possibilities. Etching is used, not only for diagnosis of minerals, but also to develop structures, twinning, crystal boundaries, and cleavages. In these cases, the whole section is immersed in the reagent chosen for the purpose.

The final means of detecting the presence or absence of a particular element in an observed mineral is the use of micro-chemical tests. These are applied to a minute quantity of solution obtained directly from a polished surface or from an excavated particle dissolved in nitric acid. Micro-chemical tests for different chemical elements have long been known, and depend on the form and colour of microscopic crystals developed by suitable reagents in minute drops of solution. They have been seldom employed in the determination of transparent rock silicates because of the difficulty of dissolving the silicate mineral, and are never employed in ordinary routine analytical chemistry when determinations are undertaken on samples sufficiently large for visual observation without the aid of a microscope. Consequently, the delicacy and certainty of many micro-chemical tests, such as that for copper and zinc, with ammonium mercuric thiocyanate, are little appreciated by chemists and mineralogists. Mineragraphic work, however, has opened a new and important field for their application. The manipulation and testing of the minute drops of solution with the aid of a microscope is highly important in connexion with the confirmation of any particular element in a mineral of microscopic dimensions whose identity remains in doubt after the earlier examinations of colour, hardness, and etching.

3. Application of Results.

The application of the mineragraphic technique in the study of ores is twofold. Firstly, it forms an important part of ore-dressing microscopy, and, secondly, it often leads to information having an important bearing upon the genesis of ore bodies, and thus to their economic importance.

(*a*) *In Ore Dressing.*—The increased information as to the identity of the valuable minerals in the ore, the size of the grains of such valuable minerals, and the relationships to other minerals which are afforded by mineragraphic methods is appreciated by none so well as the metallurgist who is concerned with the recovery of the metals. It does not solve his problems, but he finds that the microscopic aid to vision or the representation of the microscopic relationships by micro-photographs helps him to visualize those problems more clearly, and, in particular, to ascertain the degree of fineness to which he must grind his ore if he is to separate any particular mineral without recourse to the somewhat expensive smelting furnace. For example, he can distinctly see the minute particles of gold 1-2000th of an inch thick in the antimony (stibnite) ore at Costerfield, Victoria (Figure 1)*, and thus realizes that this ore will need to be ground to that degree of fineness if the gold is to be separated from the surrounding stibnite by mechanical means. In the particular case of this Costerfield ore, it obviously would not be economical to separate such finely divided gold by mechanical means as distinct from its separation from the smelted antimony metal. In other cases of gold ores, however, the precious metal is not so fine, and an operator trained in mineragraphic technique could readily afford information on which the metallurgist could base his grinding practice.

* See Plates facing page 54.

When ores consist mainly of one valuable mineral, the metallurgical problems are not likely to be difficult. More commonly, however, several economic minerals are present, and the separation is usually more difficult in proportion to their number. Thus the complex silver lead zinc ore of Broken Hill contains three silver minerals, two lead minerals, and one zinc mineral. Copper ores, too, frequently contain several copper minerals. In crushed ores of this complex type, three or more groups of mineral particles may be found, namely, (i) free grains of each mineral, (ii) grains consisting of two minerals, (iii) grains containing three or more minerals. The finer the crushing, the greater the tendency is for the associated grains to break down into individual particles, each consisting of one mineral only, and all these circumstances have to be borne in mind when such questions as the relative capacity for flotation of the different minerals are considered.

The importance of the size and relationships of the ore minerals in experimental treatments of a complex ore has lately been illustrated in a hematite silica ore from Cuyuna Range, Minnesota[1]. A lawsuit hinged on the possibility of concentrating the material to make it marketable. After methods of washing utilized in iron ore concentration had failed to give results at all satisfactory, an examination by mineragraphic methods showed the presence of innumerable silica grains averaging 1-200th inch in diameter, which clearly eliminated any present-known commercial method of concentrating material of this type. Another case from the same district involved the possibility of concentrating magnetite in magnetite slates. The microscopical examination showed that the slate required grinding to pass 200 mesh to attain even an approximate separation of the magnetite and the gangue. The treatment of the ore was thus indicated as uneconomic, and the determining factor was the texture and size of particles.

When questions of magnetic concentration arise, it becomes important to know of the presence of minerals, other than magnetite, which have a greater or lesser degree of magnetism. In an example from Fierra, New Mexico, sulphides in considerable amounts are encountered in the iron ore, and cause difficulty in keeping the sulphur down to or below an allowable maximum percentage in the final iron concentrates. A series of tests of magnetic concentration, by which it was hoped to raise the grade of the ore and at the same time save the copper, were unsuccessful. Subsequent micrographic examination, however, showed that this was due, not only to the presence of pyrrhotite (magnetic pyrites), but also of cubanite ($CuFe_2S_3$), a decidedly magnetic copper sulphide, which mineragraphic work has proved to be a rather common microscopical constituent of cupriferous pyrrhotite ores. Here, again, had micrographic examination preceded the much more costly attempts at magnetic separation, much expense would have been saved.

The explanation of losses in silver in the gravity concentration of silver-lead ores has also been found by microscopic examination. For instance, galena often contains minute particles of the silver-bearing mineral, tetrahedrite, which has a much lower specific gravity than the galena. Some particles of tetrahedrite may be sufficiently large to be

(1) G. M. Schwartz Ore Dressing Microscopy Ch. XIII. Laboratory Investigation of Ores. Edited by E. E. Fairbanks (New York McGraw-Hill Book Co., 1928).

isolated during crushing, and cannot possibly be caught on gravity-concentrating tables designed to catch galena (PbS), and thus a corresponding amount of silver is not recovered with the lead.

In addition to the minerals of economic value, valueless metallic minerals, especially pyrite and pyrrhotite, occur in many ores. The microscopic examination of polished surfaces readily reveals such minerals and their approximate amounts, and may suggest a means of excluding them. The significance of their manner of association is illustrated by the case of some titaniferous magnetites, where it is found that part of the ilmenite is so intimately intergrown with magnetite that there is no possibility of separating them mechanically. The utilization of such ores is thus found to involve the application of some smelting process rather than the elimination of titanium by any milling or mechanical process.

(*b*) *In Ore Genesis.*—The observation of the constituent minerals and their relationships often yields information bearing directly on the genesis of the ore bodies, and this, in its turn, to indications of outstanding value from the point of view of the proper development of lodes and their most effective prospecting. For example, not infrequently, evidence is found of the process of conversion of one mineral into another mineral, which in turn leads to the explanation of enrichments in copper and silver ores, or of the changes that may take place with increasing depth within an ore body.

Sometimes, too, it is found that the contacts between different minerals are sharply jagged, indicating an attack of one on another, and deductions can then be made concerning the order of deposition of the different minerals. For example, when crystals of pyrite at Captain's Flat, New South Wales, are embedded in sphalerite, they are highly corroded, while pyrite crystals in the same ore retain their characteristic crystal form when embedded in quartz. It can be clearly inferred that the development of later formed sphalerite has absorbed portion of the iron from the earlier formed pyrite. Many significant structures, including micrographic structures, zoned structures, corrosion structures, and deformation structures, may occur in a polished section of ore, and all, in one way or another, signify important stages in the changes and developments of ore bodies.

An illustration of this type of evidence is given in Fig. 2, where chalcopyrite ($CuFeS_2$) is partially replaced by covellite (CuS) in an enrichment at Moonta, South Australia. The covellite forms a network of veins in chalcopyrite, and is found in other parts of the section to increase proportionately with the decrease in chalcopyrite, until areas of covellite are developed containing little or no traces of the primary chalcopyrite.

Similar evidence sometimes explains the character of silver enrichments, and may bear directly on the formation of primary as well as secondary ore shoots, thus leading to information of outstanding value to engineers charged with the development and prospecting of properties.

4. Work in Australia.

The introduction of mineragraphic work into Australia is the result of several factors which it may be of interest to review. The first realization of its importance to the mining industry of Australia

was the outcome of an extended world tour for the study of mining geology on the principal mining fields of Africa, Europe, and America undertaken by the author in 1922-23. During this tour, the extensive growth of this method of research on commercial ores was observed in the United States of America, and, at the same time, a knowledge was acquired of the methods employed by the pioneers at Harvard, Yale, and Leland Stanford Universities. The opportunity for the development of the technique in Australia came with the author's appointment, shortly after his return to Australia, as Research Fellow of the Melbourne University in 1924-26. The work cannot be lightly undertaken, for it is common knowledge among geologists that the use of the petrological microscope and the recognition and observation of the optical properties of rock minerals requires a skill that is only slowly acquired, in the first instance, with the assistance of lecturers and demonstrators in our universities. It will be readily understood, therefore, that the training in the behaviour and properties of ore minerals is similarly laborious, and the slow initial development of mineragraphic work in other countries as well as in Australia, which makes it appear as if geologists were indifferent to the scope and value of this special field of investigation, is really due to the difficulties encountered by the unassisted worker in acquiring the necessary experience.

The main product of the researches of the author during his tenure of the Research Fellowship was a paper entitled "Observations on the Mineral Constitution of the Broken Hill Lode," published by the Australasian Institute of Mining and Metallurgy in 1926. No less than eighteen sulphide minerals were found to occur in the Broken Hill ore, ten of which were previously unrecognized, and the silver production was traced to the presence of three unrecognized silver-bearing minerals. The advance that was made was such as to attract the attention of leaders of the Broken Hill mining industry, and, when the probability arose that this new class of work would be abandoned in Australia, a concerted effort was made by those interested to retain the author in Australia, and to give the mining industry of Australia the benefit of the new weapon of investigation.

The outcome of the representations then made was the formation of a Mineragraphic Investigations Committee with the author as full-time investigator, the cost of which was to be divided by agreement between the C.S.I.R. and some of the leading mining companies in Australia, acting through the executive of the Australasian Institute of Mining and Metallurgy. This Committee started work in January, 1927.

In these circumstances the author entered upon an examination of the ores of our principal mining fields. Investigations were first continued on the Broken Hill sulphides, and embodied in a paper, "Observations on the Secondary Copper and Silver Sulphides in the Broken Hill Lode," published by the Australasian Institute of Mining and Metallurgy in 1927. Three more silver-bearing sulphides were recognized in the secondary ore, and their origin traced to the alteration of the primary sulphides. The continuity of the investigations was then broken for a period of seventeen months, as the author was requisitioned to conduct a geological survey of the Kalgoorlie gold-field.

An incidental result of this survey was the collection of a number of telluride-bearing ores, which the Mineragraphic Committee decided

to use in order to determine if any new light on the occurrence and association of the rare gold-bearing tellurides could be obtained by mineragraphic methods. A fair measure of success has now been obtained, and the results are likely to be completed before very long.

The research on the Kalgoorlie tellurides has proceeded concurrently with a considerable number of minor examinations. Requests are periodically being received from the Development Branch of the Prime Minister's Department (formerly Development and Migration Commission) for information on ores from all parts of Australia. These requests have been acceded to as far as possible, and in the aggregate a considerable amount of information has been prepared. The more recent examples include descriptions of the zinc-lead ores of Captain's Flat, New South Wales, the copper ores from Moonta, South Australia, and the copper-tin ores from the Oonah Mine, at Zeehan, Tasmania; and of these a report on the last-named is in the press. These requests are significant of a growing realization of the new and wide field of research on Australian ores that has been opened by the use of the reflecting microscope, and that is awaiting exploration.

British Wool Industries Research Association.

Membership of Australian Firms.

During his recent visit to Great Britain, the Chief Executive Officer of the Council (Dr. Rivett) was given ample assurance that Australian firms and individuals would be welcomed as members of the British Wool Industries Research Association at Leeds. The results of the work of the Association are undoubtedly of considerable interest and importance to the whole of the Australian wool industry, and in particular to manufacturers of woollen and worsted goods. It has accordingly been thought that the following account of its constitution and activities might be of some value.

The Association is one of the twenty or more co-operative industrial research associations formed some years ago at the instance of the British Department of Scientific and Industrial Research, and partially supported by the Department, generally on a £1 for £1 basis, with contributions made by the industries themselves. The objects of the Association are:—

(*a*) To promote co-operation amongst wool producers and wool-using firms, with a view to investigating the problems met with in the woollen and worsted industries.

(*b*) To co-ordinate existing means of research, and further their development.

(*c*) To avoid waste, utilize by-products, and enhance the quality and quantity of wool, and the materials into which it is manufactured; and

(*d*) To provide new uses for wool (e.g., as an insulating medium) by creating new demands and widening its application.

Membership is open to British corporations carrying on business in the production or marketing of wool, or any processes in which wool is wholly or in part used as the raw material, and to those British subjects carrying on such businesses as members of a British firm.

The results of the work of the Association are made available to all members. Members have also the following additional privileges:—

(i) To put technical questions to the staff of the Association, and have them answered as fully as possible within the scope of the research organization.

(ii) To recommend specific subjects for research, and through the Council of the Association to have a voice in the selection of the programme of research.

(iii) To the use without charge, or on reduced terms, of any patents resulting from research.

(iv) To ask for a particular research for their sole benefit at cost price, provided this can be undertaken without detriment to the general programme.

(v) To receive confidentially, in convenient form, such results of researches as the Association decides not to publish openly.

(vi) To receive regularly the output of an information bureau devoted to the industry, and thus to be kept in touch with scientific and technical development at home and abroad.

The cost of membership varies with the size of the business of the member concerned. The present scale of contribution is as follows:—

Group.	Amount of Capital.	Unit of Subscription.
	£	£
A not exceeding	20,000	5
B „ „	40,000	10
C „ „	60,000	15
D „ „	100,000	20
E „ „	200,000	30
F „ „	400,000	50
G „ „	700,000	75
H „ „	1,000,000	100
J „ „	2,000,000	200
K „ „	3,000,000	300
Z above	3,000,000	One hundred pounds for each million or part thereof

Firms not wishing to disclose their capital may agree to subscribe to a group of higher value than that in which the capital of their business actually falls in the above scale. The group for which any member may subscribe shall be made known only to the secretary and auditors of the Association.

The present and future activities of the Association were the subject of no little consideration at the Imperial Wool Research Conference held in Great Britain in August, 1930. This Conference was thoroughly representative, being attended by leading research administrators of the Empire (the Australian representatives were Dr. A. C. D. Rivett, Sir Charles Martin, Dr. R. H. Seddon, and Mr. W. P. Devereux). One of the objects of the Conference was to discuss Empire wool research, with a view to the preparation of a co-ordinated scheme and the avoidance of costly overlapping. The resolutions passed by the Conference included statements that the continuance and intensification of scientific investigations into problems of wool production in the principal wool-producing countries of the Empire are of paramount importance; that the Conference was impressed with the valuable work being carried out by the Wool Industries Research Association at Torridon; and that an appropriate division of effort as between the Association and the wool-producing parts of the Empire would be for the Association to be responsible in the main for investigating problems relating to the manufacture or utilization of wool, and for the research authorities in the wool-producing countries to be mainly responsible for investigations into problems relating to the production of the raw material, including the nutrition and health of the sheep. Incidentally, the resolutions of the Conference also contained an expression of the opinion that investigations should be undertaken to ascertain more precisely the uses to which Empire wools are put, the possibility of developing new uses, the requirements of manufacturers, and changes in demand and methods of utilization.

The resolutions of the above Wool Conference were subsequently endorsed by the Research Committee of the Imperial Conference, and subsequently by the latter Conference itself. The future development of wool research in the Empire will accordingly be in the direction

of all problems of wool utilization being in the main investigated by the British Wool Industries Research Association, whereas the problems of wool production will be left to the research authorities in the wool-producing Dominions. So far as the Australian wool industry is concerned, therefore, the wool producer will be served by the Council (through its Divisions of Animal Health and Animal Nutrition, and to a lesser extent through its other Divisions). Little work, however, will be carried out by the Council into the many problems with which the manufacturer of woollen goods is confronted. The latter would, accordingly, be well advised to give earnest consideration to the idea of joining this active and well-organized Association, thus obtaining the many significant advantages which it can offer him. As the Commonwealth Government has withdrawn its contribution to the Association, there is now no other way for Australian firms to obtain the confidential information and other advantages of membership but by themselves becoming members. The C.S.I.R strongly urges all manufacturers to join. The Association may be approached directly (address: Torridon, Headingley, Leeds) or through the Council.

The Kidney Worm of Pigs: Its Growing Importance to Australia.*

By I. Clunies Ross, D.V.Sc., Parasitologist, Division of Animal Health.

Live pigs in Australia equal in number one to every seven people. In the United States of America, the number of pigs slaughtered annually for human consumption is approximately one for each two people. These figures indicate the considerable possibilities for an increase in our pig population. Fortunately, Australia is free of such diseases as Trichmosis (due to a special muscle parasite), while swine fever is practically non-existent. There are other troubles, however, which, if not checked, may militate against success in the expansion of the pig-raising industry, such as that under review, the kidney worm.—Ed.

During the past two years, increasing attention has been directed towards the importance in Australia of the so-called "kidney-worm" of pigs, *Stephanurus dentatus*. This parasite is found in the adult stage in small fibrous capsules which open into the pelvis of the kidneys or the ureters, while larvae and immature adults are also found in the liver, in the lungs, or wandering throughout the chest cavity and the sub-lumbar muscles.

1. Distribution and Incidence.

The parasite is essentially an inhabitant of tropical and sub-tropical regions, and is firmly established on the east coast of Australia as far south at least as Sydney. It is, however, extremely uncommon in the south of the continent, heavy infestation with the parasite disappearing not far south of Sydney. In Southern Queensland, and on the north coast of New South Wales, the incidence of the parasite is extremely high, up to 50 per cent. of all pigs being found infested in certain districts, while even at the Homebush Abattoir (Sydney), in aged pigs, an incidence of as much as 56 per cent. had been recorded recently after examination of 400 adult carcasses. In young pigs at this centre, however, the incidence was much less.

* See also Plate 1, facing page 54.

PLATE 1.

(The Kidney Worm of Pigs. See page 30.)

FIG. 1.—Nodules on skin of pig caused by penetration of the larvae. Photograph taken eleven days after artificial infection.

NOTE.—Ten days later the lesions had practically disappeared, the larvae having moved onwards.

FIG. 2.

FIG. 3.

FIG. 2.—Guinea pig liver, fourteen days after being fed larvae, showing the effects of their migration.

FIG. 3.—Ureter, showing the cysts surrounding it. In these the mature kidney worm is situated.

PLATE 2.

(Mineragraphic Investigations. See page 20.)

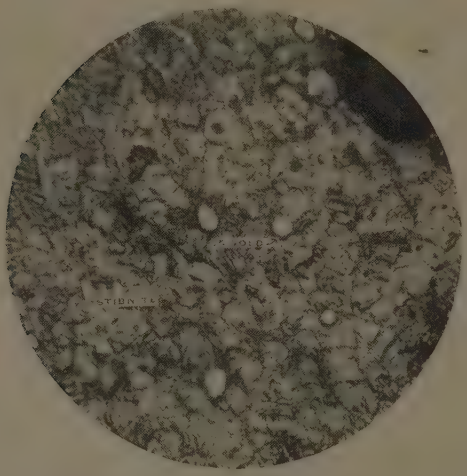

FIG. 1.—Massive Antimony Ore, Costerfield, Victoria. Mag. 200 diams. Four isolated particles of gold (white) are clearly distinguished from the stibnite (grey). The stibnite is etched with KOH, showing the shape and size of the constituent crystals.

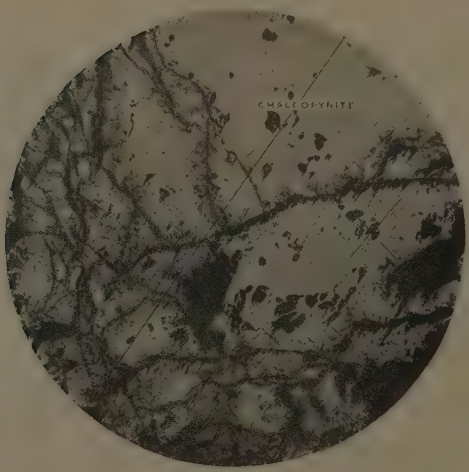

FIG. 2.—Copper Ore, Moonta, S.A. Mag. 70 diams. The area of chalcopyrite is intersected by cross cutting lines of covellite. It represents a partial conversion of chalcopyrite into covellite, with an increase in copper value.

Owing to the growing importance of this parasite, the opportunity was taken to investigate the problem of its control, and through the cordial co-operation of the University of Sydney, it was possible to make use of the services of Dr. G. Kauzal, Pastures Protection Board's Research Assistant in Parasitology, for this purpose. Besides carrying out an investigation of the life-cycle of the parasite, and a survey of the incidence in New South Wales, from which the above figures are taken, Dr. Kauzal, with the writer, has also considered the prophylactic measures necessary to check the spread of this infestation. Dr. Kauzal's observations on the life-cycle of the parasite differ materially from those of previous investigators, and show some divergence from those obtained as a result of research carried out simultaneously in America by Schwartz and Price. They may be summarized as follows:—

2. Life Cycle of Stephanurus dentatus.

The eggs of the parasite pass out of the body of the pig in the urine, and hatch in a minimum period of 16 to 24 hours. The larvae, which are microscopic in size, now develop in the mud contaminated with droppings and, in about five days, after undergoing two changes in structure, reach the stage at which they are able to infest pigs. In this stage, they are able to survive for as long as five months under suitable conditions of heat and moisture, but rapidly succumb to desiccation and to low temperatures. Infection of the host—the pig—may now be brought about with equal facility either through the larvae being swallowed by the pig, or through their active penetration of the animal's skin. In either case, the larvae ultimately reach the liver. Here they grow rapidly while wandering amongst the liver-tissue, and are frequently found in the large blood vessels of this organ. Aberrant forms are also found at this time in the lungs and other situations. It is only after five or six months' development that the now adult, but still immature, worms pass onwards to take up their final position in the vicinity of the kidney or ureters, where their presence gives rise to the formation of the little fibrous sacks in which the male and female worms are found.

3. Pathological Importance.

The presence of the adult worms leads to the formation of a great over-growth of the fatty tissues surrounding the kidneys and ureters. However, there is definite evidence that, of itself, this seldom if ever interferes with the health of the pig, though at times it produces a cystic condition in the kidney. In America, this parasite is considered a causal factor in the production of the so-called posterior paralysis of pigs, which is also seen frequently in Australia. But there is no conclusive evidence of this assumption. The fact that all developing larvae must pass through the liver is evidence that the kidney worm is of much greater pathogenic importance than was formerly supposed, since it has been found that during this passage through the liver and its stay in the blood vessels of that organ, the worm gives rise to great destruction of liver tissue, and may cause serious thrombosis of the blood vessels. Even where this does not lead to the death of the animal, the consequent fibrous formation and liver derangement may lead to serious interference with normal liver function, the effects of which may be shown in stunted growth and abnormal development. In this connexion, it is important to note that in the Philippines, this

parasite is considered to be one of the most serious causes of mortality in pigs, and there is little doubt that much previously unrecognized mortality and loss in Australia is due to its effects.

4. Economic Importance.

As in the case of two somewhat similar diseases in Australia, namely, onchocerciasis or "worm nodule disease" of cattle, and caseous lymphadenitis, or "cheesy glands" of sheep, the importance of the kidney worm depends more upon its economic, than upon its pathogenic, effects. It has long been the practice in Australia to remove the affected kidneys, peri-renal tissues, and livers, on post-mortem examination at the abattoirs, and the loss from this alone is considerable, both in this country and the United States, in the latter country being estimated to amount to millions of dollars annually. During the last year, however, the gravity of these lesions has been increased very considerably owing to the fact that efforts are now being made to build up an Australian export trade in pork. Because of the stringent regulations in force in Great Britain, it is considered highly inadvisable to export to that country pork carcasses from which any tissues have been removed. Carcasses grossly infested with *Stephanurus dentatus*, and from which it is necessary to remove the kidney or other renal tissues and the liver, or in which the sub-lumbar muscles and the tissues in the chest cavity have been mutilated for the removal of wandering larvae, must be rejected. Just how serious this rejection of carcasses may be is brought out by the fact that, of certain small batches of pigs slaughtered under careful examination, 62 per cent. have been found more or less affected, while of all pigs examined at the same northern centre the figure is still very high. Though this does not mean that such carcasses are entirely condemned, it is impossible to exaggerate the importance of the disease in relation to our expanding export trade in pork to England, this infestation standing, as it does, in much the same relation to the pork industry as caseous lymphadenitis does to the mutton industry.

5. Preventive Measures.

In regard to prevention, it is first necessary to consider the possibility of restricting the spread of this disease to those parts of Australia which are not already infested. In this connexion, it seems evident from observations on the eggs and free-living larvae that there is little risk of this parasitic infestation spreading from its present southernmost limit (somewhere north of Merimbula, on the south coast of New South Wales) since suitable conditions of temperature necessary for the stages in the life-cycle outside the body of the pig do not exist further south. For example, at a temperature of 41° F. (5° C.) (which is well above freezing point), all eggs are killed in a few days, and no development takes place under such conditions. It has also been shown that eggs and larvae are very little resistant to desiccation, especially at high atmospheric temperatures, and that therefore the condition is unlikely to assume serious proportions away from the high rainfall areas of the coast.

While the present research has brought out these reassuring features in regard to the possibility of a marked extension of the condition in Australia, it has not lessened the urgency for determining whether it is possible to decrease the present very serious degree of infestation in some of our most important pig-raising areas.

In the first place, it must be understood that no relief can be expected from medicinal treatment of already infested pigs, owing to the fact that no drug can be relied upon under practical conditions to reach the adult parasites in their situations outside the alimentary tract and the blood stream.

6. Prevention.

Nevertheless, it is now possible to suggest prophylactic measures which will help materially to decrease the degree of infestation and, indeed, actually to eradicate completely the parasite on properties where the owners are prepared to carry out such measures. It is necessary, however, to insist that pig-raising must be placed on a very different basis to that so often adopted in Australia to-day. It is useless to expect that the position in regard to kidney-worm infestation can show much improvement while pig-owners are content to keep pigs under sanitary conditions which are not only uneconomical, but really a disgrace to the industry. Ill-drained, dirty, and insanitary yards will remain hot-beds of infection with the kidney-worm, whereas in well-drained and clean sites or sanitary yards, it is possible to decrease the danger of infestation immediately, and even to effect complete eradication. Every accumulation of mud in a pig-yard is a possible potential source of infection, whereas with drainage and sunlight, risk of infection disappears.

Even where pigs are running in large yards, it is possible to kill the infective larvae in the mud by treatment with chemicals at regular periods throughout the summer and autumn. A scheme is being devised whereby, in the light of our investigations, it will be possible, with subdivision and treatment of yards, to raise young pigs free from kidney-worm infection, thus ultimately to build up a stock of clean pigs, and to effect complete eradication of the disease. This will be the subject of a further communication.

Sheep Branding Fluids Non-injurious to Wool.

For some time past, the British Wool Industries Research Association has been investigating various mixtures used for branding sheep. By reason of its close contact with numerous English concerns working up raw wool into manufactured products, the Association has been able to give special attention to the effect, from the manufacturers' point of view, of the different branding materials now commonly used. In Australia, such information is somewhat difficult to obtain, and an account of the Association's work thus becomes of interest. The Association made the results of such work freely available to the Chief Executive Officer of the Council (Dr. Rivett) during his recent visit to Great Britain. Two publications* dealing with the matter have also been published by the Association, and much of the information in the paragraphs that follow has been drawn from them.

The first paper issued reviewed the sheep-branding problem from the three stand-points of the wool-grower, the manufacturer of sheep-

* Tar on Wool: Its injurious effect as a sheep-marking medium and the provision of effective substitutes. *The Wool Record and Textile World*, 7th and 14th October, 1926.
Sheep marking without injury to wool. Report to Empire Farmers' Conference, London, 1928.

marking mixtures, and the wool user, pointing out that if these interests were to be reconciled a mutual understanding, then non-existent, of the requirements from all points of view was essential. It also contained a report on actual tests made upon a number of commercial branding agents, and some 40 experimental fluids, the latter designed to satisfy the three-fold requirements of durability during exposure, removal on scouring, and low cost.

From the point of view of the wool scourer, coal tar and pitch are both very objectionable ingredients of any branding fluid, so much so that the Association has even proposed that a ban should be placed on all black branding materials. In many wool-producing centres, the objections to coal tar and pitch are now well known, but there is a tendency in some parts to replace them by unscourable paints, which are almost as objectionable. A mixture developed by the Association in the early stages of its investigations had the following composition:—

	Parts by Weight.
Wool fat	45
Lime blue	5
Barytes	20
Emco (light paraffin spirit)	25

(The Emco spirit is a petroleum product of less volatility than petrol, and is of the grade frequently used as a substitute for turpentine.)

A branding mixture made to the above formula is quite easily removed in scouring operations; and under the climatic conditions that exist in the British Isles, it is also quite satisfactory from the point of view of durability on the sheep. It has not, however, been extensively tested for durability under the more severe conditions of the Dominions.

Recently the Association has endeavoured to develop a branding mixture that is more lasting under the extreme conditions of the more distant parts of the Empire, including Australia. It has now developed such a mixture with the following composition:—

	Parts by Weight.
Wool fat	30
Resin	20
Carnauba wax	3
Kieselguhr	18
Ignited iron oxide	6

Emco spirit to desired consistency.

Any Australian sheep-owner using a branding fluid made up to the above formula can do so with the full knowledge that his brand will be easily removed in the scouring operations, and that the mixture will in all probability satisfy his requirements as to legibility after the exposure of his sheep over long periods. The brand will, however, be of a reddish colour owing to the presence of the ignited iron oxide.

The preparation of the mixture in small quantities would not be attended by any great difficulty. For large quantities, the following procedure was adopted by the Association, in four steps:—

1. Melting of resin, wax, and wool fat ("Base").
2. Letting down with portion of solvent, sufficient to keep reasonably fluid ("Varnish").
3. Mixing "varnish" with filler or extender and pigment ("Mix") and remainder of solvent to consistency required.
4. Grinding the "mix" in a circular type mill, and packing.

(1) For the first step, the plant used was a 1,600-gallon jacketed melting-pan, with stirrer and withdrawal pump, heated by oil circulation. Thirty hundredweight of resin are tipped in. As the melting proceeds, the temperature of the mass is read with a long metal sheathed thermometer (dial type.) The mass should be practically fluid at 200° F. Then 4½ cwt. of wax are added, and the stirring gear carefully engaged to avoid jamming with lumps still semi-solid. The supply of heat is now reduced, and the wool fat tipped in in 2-cwt. barrel lots. (The loops and staves were stripped off, and the lump let in as gently as possible, with stirrer stopped. Manipulation by poling is wanted at the start. Later additions give little trouble.) Forty-five hundredweight of wool fat in all are added. Attention must be paid to the temperature, as the chilling of the resin through addition of cold wool fat must be avoided. (It would be preferable to have a separate melter for the wool fat, and to run the molten fat into hot resin wax mixture.) As a guide, the temperature at the end of mixing should be 150° F., and with heat off is continually falling.

The addition of wool fat may give rise to considerable frothing of the hot base, with danger of overflowing if the resin is too hot, owing to water getting into the wool-fat barrels. By fitting extra blades to the stirrer so that the upper blades skim the surface, this frothing can be kept under control. The removal of any water so introduced is essential to the production of a good fluid, and it must be driven off before further processing.

(2) The varnish must not be allowed to set even semi-solid, and it is necessary to prevent this by adding a proportion of the white spirit to give a fluid varnish which can be pumped (or run by gravity) to the mixing mill. Great care is necessary to avoid fire risk, as some spirit is inevitably lost by evaporation. Usually, additions of 2 cwt. lots should be made until 28½ cwt. of spirit have been added. The gravity of the "varnish" should be 9¼ lb. per Imperial gallon at 60° F.

(3) For the mixing of the varnish with the filler, a vertical pugging mill was used. Each batch put through consisted of—

84 lb. kieselguhr,
28 lb. colour oxide,
336 lb. "varnish,"
8 lb. spirit,

giving 456 lb. of "mix." The figure of 8 lb. of spirit should be adjusted for each batch by supervision of the product of (4). If this comes too thick, it must be returned to the pug-mill, and further spirit added, as spirit must not be added in (4).

(4) The "mix" from (3) was run directly into the feed hopper of a circulating type water-cooled mill, and discharged directly into containers. The consistency as packed should, of course, be slightly stouter than required by the user, rather than thinner. The gravity of the finished fluid should be 11¼ lb. per Imperial gallon.

The above mixture is a comparatively cheap one to prepare; its cost in England is about 1s. 6d. per gallon.

The Association has made the foregoing information freely available, and no exclusive rights to the manufacture of the branding fluids mentioned exist. Any one in Australia who cares to do so is thus quite free to use the formula.

Black Disease in Tasmania.

By D. T. Oxer, B.V.Sc., Veterinary Pathologist, Department of Agriculture, Tasmania.

The article that follows is descriptive of work carried out by an officer of the Tasmanian Department of Agriculture. It deals with a subject which has been comprehensively investigated by the Council, particularly in so far as the disease on the mainland is concerned (see the Council's Bulletin 46). The article is published with the kind permission of the Director of the Tasmanian Department.—Ed.

PART I.—HISTORY AND DESCRIPTION.

Introduction.

In Tasmania, a disease of sheep has been known for many years, marked by its seasonal occurrence, by the suddenness with which death occurred, and by the rapidity of post-mortem decomposition. There is reason to suspect, from the information available, that this disease was similar to that which has been since described by various investigators under the name of Black Disease in New South Wales, and Infectious Necrotic Hepatitis in Victoria.

In 1906, Willmot (1), Government Veterinary Surgeon, mentioned an investigation into sudden mortality in sheep at New Norfolk. No details were given other than the fact that deaths were extremely sudden and putrefaction rapid. In 1910 (2) he gave a description of "weaner" disease, which occurred seasonally from the beginning of June to the end of August, and which was apparently causing Tasmanian sheep breeders some concern. As his description was based on autopsies made some time after death, no conclusions can be drawn as to the cause of the disease. He was of the opinion, however, that it belonged to the braxy group of diseases.

In 1909, the assistance of Dr. Gilruth was sought in elucidating the cause of a disease in sheep locally known as "hogget disease". His report was published in 1910 (3). He stated that the disease was most common in the months of August and September, and was confined to "sheep, and particularly young sheep (hoggets), in good condition." The description of autopsy on a hogget which had died during the night was given, and necrotic areas in the liver were described. The second sheep, which was slaughtered in the last stages of an acute disease, was examined, but no mention was made of necrotic areas in the liver, stress being laid rather on a necrotic lesion in the abomasum. A description of subsequent bacteriological examination was given, but as the material was taken from a sheep which had been dead for some time, the conclusions reached could not be regarded as final.

Later, Gilruth (4), in comparing the Tasmanian disease with the disease of sheep in Victoria, was of the opinion that the two were similar, although the organism isolated and regarded by him as the cause were slightly different. Necrotic areas and fluke infestation were usual findings at autopsy. He also was of the opinion that a disease of sheep in New South Wales called the "blacks" would, from its description by stock-owners, be found similar to that in Victoria. This has been shown to be the case by subsequent investigations, since Dodd (5) fully described black disease of New South Wales, concluding that death was due to an acute toxaemia, and that the primary lesion was a necrosis of the liver, in which the causal pathogen was found in a state of purity at the time of death. He was of the opinion that the

liver fluke was a mechanical carrier of the disease. Edgar (6), in 1929, described the causal organism, showing it to be of the *B. oedematiens* type.

In 1921, Albiston (7), in describing a braxy-like disease of sheep in Victoria, which he named infectious necrotic hepatitis, showed that the disease was similar to that described by Dodd, and suggested that the necrosis caused by the young liver fluke, during its migration to the liver from the alimentary canal, provided a suitable nidus for the growth of the causal organism. The bacillus isolated by him was considered to bear some similarity to *B. oedematiens.* In 1927, Turner and Davesne (8 and 9) fully described the organism isolated by Albiston, and proved it to be a strain of *B. oedematiens.* Turner has more recently, in 1930, published the results of exhaustive investigations into all phases of the disease (10). Although the disease has not been typically reproduced in sheep, sufficient data has been obtained from experiments carried out in small animals, and from observations on the pathology of the lesions in sheep, to show that there is a germination of latent spores of *B. oedematiens* in the necrotic areas, caused by young flukes wandering in the hepatic parenchyma. Death is caused by absorption of toxins from the developing organisms.

Local Investigation.

Efforts have been concentrated during the last two years towards proving definitely whether the Tasmanian braxy-like disease is, or is not, identical with that of Victoria and New South Wales, so that suitable measures might be taken for its control and prevention. To this end, a large number of post-mortem examinations were made, in all of which lesions were found similar to those typical of black disease in Victoria and New South Wales. Absolute confirmation could not be obtained, however, until a post-mortem examination on an animal immediately after death could be made. It was not until the beginning of 1930 that fresh material was obtained in an outbreak of the disease on a certain property. The symptoms, post-mortem examination, and subsequent examinations of one case will be described.

The owner of a particular property had experienced heavy losses during the last few years. The disease was seasonal in occurrence, mortality being heaviest in Autumn. The outbreak to be described commenced in November, 1929, in a flock comprising 1,000 lambs and 1,400 adult ewes and rams. Approximately 80 deaths occurred from the beginning of November, 1929, to the beginning of March, 1930. The sheep affected were mainly two-tooth ewes and rams, but older sheep were also lost. No lambs had died of the disease. Death was always extremely sudden, and was followed by rapid decomposition. Carcasses of dead sheep were usually found in the mornings, death having occurred, apparently, without a struggle.

It was not until the middle of February that suitable material for examination was obtained, when a sheep was watched carefully from the time of first showing symptoms to the time of death. The subject was a large-framed ewe in good condition, in a flock which had at all times had access to river frontage or marsh. There had been twelve deaths in the preceding four or five days.

Symptoms.

The ewe was first noticed because she refused to rise when approached. The ears were slightly drooping, and there was an anxious expression on the face. Slight incoordination of movement of the hindquarters was noticed when she got up. After moving a few paces, she stumbled slightly with one forefoot and moved off with a careful restricted gait. She lay down several times, eventually coming to a fence, against which she lay with the head resting on the lowest wire. At this stage—one half-hour after first being noticed—breathing was very much accelerated. At the end of the next half-hour, respirations were 42 per minute—slightly lower than before—and accompanied by a slight grunt at the end of expiration. The neck was stretched out, with the head resting on the ground. The heart beat was very rapid, irregular, and weak. The mucous membranes of the eye were injected. When placed on her feet she staggered a few paces, stopped, swayed from one side to the other, and fell over. Five minutes later the animal was again placed on her feet, but after standing for a minute sank to a kneeling position, and then lay down. In five more minutes she lay on the left side with the head thrown back, gave a slight convulsive movement, and after four deep gasps died without a struggle. Death occurred one and a half hours after the animal was first noticed.

Post-mortem Examination.

Visible mucous membranes were congested. The anal sphincter was relaxed with slight prolapse of the rectum. The subcutaneous tissue appeared slightly congested, but there was no oedema. The mammary gland was congested. Superficial lymph glands slightly congested. In the abdominal cavity there was an excess of sanguineous and slightly cloudy peritoneal fluid. The capillaries of the fenestrated portion of the omentum were markedly injected, while the portion in opposition to the caudate lobe of the liver showed very marked petechiosis. The parietal peritoneum was injected, while the peritoneal covering of the duodenum and the lesser omentum showed petechial spots of various sizes. The root of the mesentary was oedematous. The hepatic lymph gland was very congested, the mesenteric glands being less so. There was only slight congestion of the abomasum, but there were areas of blood extravasation on the duodenal mucous membrane. The remainder of the alimentary tract was abnormally congested. Kidneys showed some congestion.

The liver was enlarged, firm, and very much engorged with blood. The caudate lobe showed, under the capsule, an irregular, yellowish, necrotic area about ½ inch in diameter, surrounded by a zone of inflammation. Under the capsule elsewhere could be seen a large number of small pin-head areas of necrosis. The edge of the lobe showed a leucocytic aggregation, which could be scraped off as a cream. On section, the large necrotic area, which was of a cheesy friable consistence, was seen to extend into the liver tissues, as did the small areas of necrosis. No necrotic areas were seen in any other portion of the liver.

In the thoracic cavity, the pericardium contained a great excess of clear, straw-coloured fluid, which quickly coagulated on exposure to air. The heart was contracted. No sub-epicardial haemorrhages were present, although sub-endocardial haemorrhages were very marked. Pleural fluid was in excess.

There was no odour from the cadaver at the time of examination. Death was due to heart failure following on an acute toxaemia.

Bacteriological Examination.

Material collected at post-mortem examination was sowed into liver broth under vaseline. Cultures sown with material collected from the large necrotic area of the liver were positive, yielding a large gram-positive organism in pure culture. Material from other tissues and fluid were negative.

Morphology.—The bacillus, a strictly anaerobic, gram-positive, sporulating rod, gave cultural and morphological results not differing essentially from those described by Turner (10) for the *B. oedematiens* of black disease. A greater tendency to filament production was present; and under the conditions of experiment, motility was not demonstrated, nor were surface colonies obtained. The organism was not tested for fermentative properties.

Pathogenicity.

Several guinea pigs were injected subcutaneously with amounts varying from 0.05 c.c. to 0.005 c.c. of 24 hour culture in peptic digest broth. The two which had received 0.05 c.c. and 0.025 c.c. died within 28 hours; the two which had received 0.001 c.c., within 48 hours; and one which received 0.005 c.c. in 60 hours.

The post-mortem appearances were similar, although varying in degree. They were characterized by a small area of haemorrhagic inflammation at the site of injection with a clear, reddish, subcutaneous oedema extending over the floor of the abdomen as far forward as the sternum. There was a general congestion of internal organs, with some excess of peritoneal fluid.

Toxin Production.

A number of guinea pigs, varying in weight from 200 to 360 gms., were on different occasions inoculated with a filtrate (through L_2 candle) of 48-hour cultures in peptic digest broth. In the three sets of experiments conducted, 0.333 c.c. constantly killed the inoculated animal, in one case in fifteen hours, and in the two others in 36 hours. In one experiment, two guinea pigs which both received 0.143 c.c., died, but this was not a constant result. Even if death was not caused, toxin in as small amounts as 0.001 c.c. caused illness, with very marked oedema extending from the site of inoculation along the floor of the abdomen.

Neutralization of Toxin.—A culture of the organism was forwarded to Dr. A. W. Turner, Veterinary Research Institute, Melbourne, who conducted this experiment. Anti-oedematiens sera prepared from the Victorian strain and from the Pasteur Institute strain, neutralized culture of the organism forwarded. Anti-*Vibrion septique* and anti-*welchii* serum did not neutralize the culture.

Microscopical Examination.

The Liver Lesions.—Microscopic examination of the necrotic portions showed that the large area previously mentioned consisted of a central area of necrotic tissue. The original structure of the liver could be discerned in this area. Towards the periphery, by using suitable staining methods, could be seen masses of bacilli. Outside

this was a zone of leucocytic infiltration consisting mainly of polymorphonuclear leucocytes and nuclear debris interspersed with eosinophiles. Outside this again was an inflammatory zone consisting largely of red blood cells. The small necrotic areas in the other parts of the lobe consisted usually of a central area of leucocytes surrounded by a zone of hepatic cells, the nuclei of which stained weakly with haemotoxylin. Outside this was an area of very marked congestion. The parenchyma of the remainder of the liver showed engorgements of the blood sinusoids with red cells. Many of the hepatic cells showed feebly staining nuclei. The portal canals showed some leucocytic infiltration.

The bacilli, which were gram-positive, and in apparently pure state, appeared to be confined solely to the large necrotic area of the caudate lobe. They were found massed at intervals along the periphery of the area, but single elements, or, at most, chains of two or three, could be seen scattered throughout the central necrotic portion. In the outer portion of the area they occurred singly, in pairs, or in chains and filaments. The longest filament measured was 62 μ in length. Single elements measured were from 2 μ to 6.5 μ in length by 1 μ in width, and had round ends. Sporulation was evident. Spores of single elements were sub-terminal, and slightly distended the bacillus. One or two spores could also frequently be seen at intervals in the filaments.

Oedema of the Head Associated with the Disease.

During the outbreak an oedema of the head varying in degree was seen in two ewes. The first of these was noticed in the morning by the fact that the head was enormously increased in size, and was carried close to the ground. The ewe died in the afternoon, and was examined within an hour of death. There was a profound subcutaneous oedema of a clear, pale colour extending from the parotid groove to the lips. The head was enlarged by approximately half its normal size. The pericardial sack was tremendously dilated with fluid. The liver was enlarged, congested, and contained a few immature fluke and numerous necrotic areas. Organisms from cultures of this liver were similar to those already described. In the second case, which was seen on the same day, and shortly after death, the oedema was confined to the muzzle, but was very marked. Post-mortem examination was similar to the previous one, with the exception that there was one large necrotic area under the diaphragmatic surface of the liver. Cultures subsequently made from this area were positive.

In 1929, Bull (12) described a condition in rams in South Australia locally known as "swelled head." From one of these he recovered *B. oedematiens,* and he concluded that a local infection of the head following on trauma was the cause of the condition.

Turner (11), while doing experimental work on vaccination of sheep against black disease, noticed a profound oedema of the head in one of the experimental animals, following on the injection of 0.5 c.c. of *B. oedematiens* culture after the animal had previously received 5 c.c. of vaccine.

General Remarks.

Speaking generally, sheep dead of the disease are usually found in the mornings. Death is rapid, and putrefaction commences very early, being well advanced in three hours' time. Careful examination has, with few exceptions, demonstrated the presence of young fluke in the livers of affected sheep.

The greatest mortality is usually in Autumn (March and April), although in the experience of one stock-owner, in whose flock the disease occurred, June and July were the worst months. In the writer's experience, August and September are not the worst months of the year, as stated by Gilruth (3).

There appears to be no particular age incidence, all ages and breeds being susceptible. The disease has not been definitely seen, however, in lambs. All the sheep seen to be affected have been in good condition.

The disease is more particularly confined to river flats, low-lying ground, and marshlands.

Summary and Conclusion.

An acute infectious disease of Tasmanian sheep is described, together with the bacteriological and pathological examinations made and tests on small experimental animals.

A necrotic area of the liver is the primary lesion in the disease, death being due to an acute toxaemia.

The disease is probably the same as that described by Gilruth in 1910 (3) as "Hogget Disease".

The bacillus isolated appears to be the causal pathogen, and is a strict anaerobe of high toxic and pathogenic power. Its morphology, staining properties, and general cultural characteristics, and the fact that anti-oedematiens sera prepared from Pasteur and Victorian strains neutralized culture, proved that the organism is *B. oedematiens.*

The disease is identical with black disease in sheep in New South Wales, as described by Dodd (5), and to "Infectious Necrotic Hepatitis" of Victorian sheep, as described by Albiston (7), and confirmed by Turner and others.

An oedema of the head has been seen in association with the disease. The condition appears similar to "swelled head" in rams as described by Bull (12).

PART II.—PREVENTION.

Following on the identification of the disease in Tasmania, and the isolation of *B. oedematiens,* immediate steps were taken towards procuring a suitable prophylactic agent for the immunization of the affected flocks.

Turner (11) has described the preparation of anaculture vaccine, which has been used with success as a preventive of black disease in Victoria.

The co-operation of the Council for Scientific and Industrial Research was sought, and by the courtesy of Dr. Gilruth, the writer was enabled to make full use of the facilities offered by the Council for the production according to Turner's formula. The vaccine was prepared from a Victorian and a Tasmanian strain, sufficient quantity being produced for use in flocks where the disease had been definitely proved to be present. Vaccination was necessarily carried out late in the season, so that no final opinion can yet be given as to its efficacy.

Results have, however, been very satisfactory, and stock-owners who have had their flocks vaccinated are highly gratified with the results so far obtained.

The following gives the available data regarding vaccination so far carried out in Tasmania, in tabular form. The vaccination is being carried out by the veterinary staff of the Tasmanian Department of Agriculture, the vaccine now being prepared in the Department's laboratory.

Date Vaccinated.	No.	Amount of Vaccine Given.	Deaths, Flocks, in 1930 before Vaccination.	Deaths after First Dose.	Deaths after Second Dose to end of 1930.	Remarks.
April, 1930 ..	6,348	2 c.c. and 5 c.c. ..	235	32	Nil	
May, 1930 ..	1,363	2 c.c. and 5 c.c. ..	50	Nil	Nil	
June, 1930 ..	600	One dose of 5 c.c.	21	1	..	Single dose given, due to lateness in season
Total ..	8.311					

Deaths after first and second doses of vaccine refer to deaths from black disease. No ill-effects, other than lameness for 24 hours after vaccination, have occurred.

Since the beginning of November to the end of December, 1930, 9,958 sheep have been vaccinated. Of these, 6,038 received a dose of 2 c.c., followed by a second dose of 5 c.c, while 3,920 received one dose of 7 c.c.—3,038 of the former had been already vaccinated in the early part of 1930, as were 1,620 of the latter group. The single dose of 7 c.c. was given on account of the difficulty of mustering sheep for two separate vaccinations. It is too early to state what beneficial results have been obtained from these last vaccinations.

Vaccine Test in Guinea Pigs.

Penfold and Parker (13) have recently described strains of *B. oedematiens.* and reported vaccination experiments on guinea pigs and sheep. The vaccine used in their experiments was an anaculture, from which the majority of the bacterial bodies had been removed by filtration through filter paper. These writers criticize the results obtained by Turner (11) in his vaccination experiments. The vaccines used by Turner, and by Penfold and Parker, appear to be essentially similar, in that they are both prepared by the culture of *B. oedematiens* in peptic digest broth for 48 hours, and subsequently detoxicated by the addition of formalin.

It has, therefore, been decided to include the results of a vaccination experiment which has recently been carried out by the writer.

The vaccine used was anaculture prepared with equal parts of a Victorian strain (BD "19") and a Tasmanian strain (Oxer) of *B. oedematiens,* according to the formula of Turner. The vaccine used was eight months old. The test doses, which were inoculated subcutaneously a fortnight after the injection of the vaccine, were from a 24-hour culture in peptic digest broth of the same Tasmanian strain as used in the preparation of the vaccine.

The following table gives the results obtained:—

TABLE I.

No.	Vaccinated, 14th November, 1930.	Tested, 29th November, 1930.	—	Weight in grams.	Death within— 9 hrs.	22 hrs.	24 hrs.	
42				360	—	—	—	
43		*5 c.c. culture subcut.	Light weight	360	—	—	—	
44				390	—	—	—	
45				860	—	—	—	
46	2 c.c. anaculture subcutaneously			710	—	—	—	
47			Heavy weight	770	—	—	—	
48		*1 c.c. culture subcut.		710	—	—	—	
49				710	—	—	—	
50				740	—	—	—	
51				740	—	—	—	
52				390	+			
53		*5 c.c. culture subcut.	Light weight	360	+			
54				330	+			
55				770	..	+	Rigor mortis present	
56	Controls unvaccinated			620	..	+	„	„
57			Heavy weight	720	..	..	+	
58		*1 c.c. culture subcut.		710	..	+	Rigor mortis present	
59				830	..	+	Rigor mortis not present	
60				860	..	+	„	„
61				740	..	+	„	„

The vaccinated guinea pigs developed a slight oedema, varying in extent, after application of the test dose, but did not appear to be otherwise affected. These guinea-pigs were kept under observation for a week, during which time no deaths occurred.

Determination of M.L.D.

Five guinea pigs were taken and injected with varying quantities of the same culture as used for testing the vaccinated guinea pigs.

TABLE II.

No.	Date.	Weight in grams.	Route.	Amount.	Remarks.
66	14·11·30	640	Subcut.	1/20th c.c.	Death occurred within 28 hours
69	„	500	„	1/40th c.c.	„ „ 24 „
67	„	640	„	1/100th c.c.	„ „ 48 „
70	„	360	„	1/100th c.c.	„ „ 36 „
68	„	600	„	1/200th c.c.	„ „ 60 „

Expressing m.l.d. in terms of amount of culture necessary to kill a guinea pig within 3 (three) days, the m.l.d. of the test culture is 0.005 c.c. It appears, then, that 2 c.c. of anaculture vaccine will protect guinea pigs against 100 m.l.d.'s of culture. This compares favorably with results obtained by Penfold and Parker, who protected guinea pigs against 10, and probably 50 m.l.d's. It, therefore, does not appear that the modification of the black disease vaccine, as

proposed by Penfold and Parker, with its difficulties of manufacture, offers any advantages over the officially-adopted vaccine prepared by Turner's method. The results obtained by us are more satisfactory than those of Turner (11), whose guinea pigs were ravaged by paratyphosus, and who tested his vaccinated animals by the intra-muscular method.

Conclusion.

The anaculture vaccine being used by us for prophylaxis in the field, and prepared strictly according to the method of Turner, is capable, even when eight months old, in single doses of 2 c.c., of immunizing guinea pigs against 100 m.l.d's of culture given by the subcutaneous route.

Acknowledgments.

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Investigations into the Chemistry of Australian Timbers.

Project No. C.1 of the Division of Forest Products.

By W. E. Cohen, B.Sc., and H. E. Dadswell, M.Sc.

The first portion of the article that follows constitutes the general introduction to Project No. C.1 of the Chemical Section of the Division of Forest Products. Work on that project is now being actively undertaken, and in some directions results of value are being obtained. Some notes illustrative of these last are given in the second part of the article.—Ed.

1. General Introduction.

Both in Europe and America, the chemistry of wood has been the subject of much research during the past twenty years. Notwithstanding, very little is known of its fundamental chemical structure. This is not due to any lack of effort or interest displayed in the investigation, but rather to the complexity of the material under examination.

Wood has been subjected to numerous proximate chemical analyses, and almost all of the existing knowledge concerning it has been derived from such analyses. The inadequacy of these methods as a means of demonstrating the true chemical nature has been pointed out by numerous investigators, as the drastic treatments necessary in such analyses may readily cause changes in structure or in the chemical nature of the original constituents. The customary analytical procedures separate the components of wood into the following groups:— Ash, extractives, lignin, Cross and Bevan cellulose, total pentosans, α-cellulose and pentosans in cellulose. Of these, the most important is the wood cellulose, which may be considered as the residue remaining after the removal of the lignin from the extractive-free wood by repeated chlorinations and subsequent treatments with sodium sulphite. Valuable general information on the chemistry of all the components of wood may be obtained by reference to any of three recent books, namely, *The Chemistry of Wood,* by Hawley and Wise; *The Chemistry of Celluose and Wood,* by Schorger; and *Holzchemie,* by Hagglund.

Recent experiments carried out by Ritter, of the Forest Products Laboratory, Madison; Harlow, of the New York State College of Forestry; and others have been invaluable in furthering the knowledge of wood structure. Micro-sections of wood have been subjected to the ordinary processes of chemical analysis, and the results of each treatment observed under the microscope. In this manner it has been demonstrated that the wood cellulose constitutes the major portion of the cell wall, that the middle lamella (cementing material between the cells) and small portions of the cell walls are isolated as lignin, and that the extractives are for the most part extraneous materials which have been deposited within the cells. Ritter has further studied the structure of isolated wood fibres by means of chemical disintegration, and has shown that they are made up of minute microscopic units termed "fusiform bodies." X-ray methods of analysis have also been used as a means of determining the structure of wood-cellulose, lignin, and wood itself.

By far the greater proportion of the available knowledge has been obtained by the study of the chemistry of the more common species

of the Northern Hemisphere. But little is known concerning the tropical or sub-tropical species. The Australian woods, for example, have never been examined systematically. Some isolated results are available, but in no instance have standard methods of analysis been employed. The value of the analytical methods of examination following a definite procedure, inadequate though them may be, cannot be denied. Some means of comparison is immediately afforded; the processes of weathering and decay can be followed; and it is highly probable that they will furnish results of value in relating chemical to physical properties. Micro-chemical studies open the way to more complete understanding of structure and its relation to chemical composition. In this respect nothing has been done with Australian timbers, and there is no proof that they will react in the same way under the same conditions of treatment used in the examination of North American species. The purpose of this project, therefore, is to obtain as much information as possible on the chemistry of Australian timbers. It is fully recognized that the task will be no easy one, but the results obtained should prove of ultimate scientific and practical value.

The scope of the project is so vast that it has been divided into a number of separate investigations, each of which is related to the others, and yet to some extent remains a definite entity. For the present, this number has been limited to five. No doubt, as the project develops, the number of investigations will be increased. For each, a working plan, outlining the purpose and the procedure to be followed in attacking the problem, will be prepared. A brief discussion of the reasons underlying the selection of each problem follows.

In the first place, a systematic examination of the chemical composition of all Australian timbers is considered necessary. The composition of the majority of American and European woods has been determined, following a definite standard procedure, which was first worked out by the United States Forest Products Laboratory, Madison. It is therefore logical that the examination of Australian woods should follow the same procedure, as in this manner the results obtained will be directly comparable. The investigation will involve—

(1) the complete analysis of authentic wood samples taken from every species;

(2) the study of the variation in chemical composition of different trees of the same species; and

(3) the study of the variation within one tree.

Owing to the fact that there are such a great number of species in the genus *Eucalyptus*, extreme care is essential in the collection of the necessary authentic wood samples for analysis. Full details for the undertaking of this problem are recorded in the working plan under Project C.1-1.

No doubt many of the results obtained under Project C.1-1 will be extremely valuable in distinguishing numerous woods. It is planned, however, to consider the identification of woods by chemical means in a separate investigation, in which the purpose will be to obtain simple tests for the use in identification of those woods difficult to separate by the ordinary procedures adopted in wood technology. In many cases, the development of such simple tests will be based on the results and experience gained in the investigation of chemical composition. However, in cases where the problem of identification is difficult,

larger numbers of authentic samples of the woods in question will have to be examined before any test is adopted. Here, again, it is absolutely essential that great care be taken in the collection of the samples necessary for the investigation. It is difficult to forecast exactly what tests will prove effective, but certain definite plans will be followed, and these are considered in the working plan for the investigation Project C.1-2.

The chemical nature of lignin and the nature of its linking with cellulose in wood are problems which have baffled the workers in this field. The methods of isolating it are such that its chemical composition is very probably considerably altered, and it is not known with any certainty whether such methods isolate only the lignin or whether other components of wood are present. The possibility of such contamination may not be great when dealing with certain woods, but it is a different matter with a large number of species of the genus *Eucalyptus*. The vessels, ray cells, and even the fibres, are often filled with extraneous materials, which apparently resist solution in the solvents used to extract wood before the lignin determination. Such materials will, therefore, be isolated as lignin, and the results of the lignin determination, even though carried out according to standard procedure, will not represent the true amount of lignin present in the wood under examination. For this reason, therefore, a study of the lignin determination, with special reference to methods for removing such objectionable materials, is planned in Project C.1-3.

Micro-chemical methods for the study of wood have proved to be extremely useful. Although the results obtained are of fundamental rather than technical value, they give rise to new conceptions regarding the complex material under examination, and afford the investigator a much clearer insight into many of his problems. The behaviour of the different elements of wood structure under various treatments can be readily observed, and their ultimate building units separated. The application of micro-chemical methods to the examination of Australian woods is planned in Project C.1-4.

The present-day methods of wood analysis, although the product of years of research, are not perfect. They undoubtedly serve the purpose of giving the investigator a general idea of the composition of the various woods. They can be classed as empirical methods, in which the procedures to be followed have been standardized. The development of better, and possibly more accurate, methods will come. Work of this nature has already been carried out by the α-Cellulose and Pentosan Committees of the Division of Cellulose Chemistry of the American Chemical Society. It is possible that some of the methods worked out for softwoods and hardwoods of the Northern Hemisphere will prove unsatisfactory in some respects when applied to certain Australian timbers. If so, modifications will have to be made to suit the investigation of these timbers. At the same time, any suitable new method of analysis will be thoroughly investigated. The details of this investigation are shown in the working plan under Project C.1-5.

2. Notes Regarding Results.

The following notes illustrate some of the lines in the investigations above outlined in which progress has already been made:—

Methods of Wood Analysis.—It has become abundantly clear that the standard procedure adopted elsewhere will need modification for

Australian woods. Many of the eucalypt woods are very resistant to the action of chlorine in the separation of cellulose. They need much longer treatment than is usual, and, as a consequence, the cellulose appears to be more or less disintegrated. One result of this is that no method has yet been found that is suitable in such cases for the determination of α-cellulose, which is the portion of the cellulose not dissolved in 17.5 NaOH solution. The repeated chlorinations cause the cellulose to become more or less gelatinized by the subsequent alkali treatment, and it is impossible to filter it. The α—cellulose determination is of value in determining the suitability of the cellulose for the manufacture of rayon and of cellulose lacquers.

Again, it has been shown that the usual method of extracting with a benzene alcohol mixture leaves behind some of the extraneous materials which frequently occur in the woods. These contaminate the lignin, and results are high. A very important diagnostic feature is the ratio of cellulose to lignin, and the above fact vitiates some of the results. Microphotographs of the isolated lignin show it to be contaminated. Work which appears to offer a solution of this difficulty is now in progress.

An illustration of the value of the anaylses in differentiating between two timbers very similar in physical appearance is the case of jarrah and karri. The microscope fails to differentiate these timbers with certainty, and even experts can be easily deceived by them. Analysis of a large number of samples of each shows that the cellulose in jarrah ranges from 38.86 to 51.98 per cent. and in karri from 55.69 to 63.74 per cent. Further, the alkalinity of the ash measured in cc. of N/10 acid varies from 0.01 to 0.16 in jarrah and 0.43 to 0.91 in karri.

It is clear from these figures that these timbers can be differentiated with certainty by the above analyses. Not a single exception to these cases has been found. The alkalinity of the ash is very quickly obtained, and this test is, therefore, particularly suitable. Many other such tests are being worked out. The field is very large.

It is impossible, for instance, at present to distinguish the timber of the two common Araucarias in Queensland, viz., hoop pine and bunyah pine. It is hoped to establish a chemical differentiation between them. There are a great number of such pairs of timbers in Australia. The chemist, it would seem, is needed as a complement to the microscopist in determining the species from which timbers are derived.

The Operations of the Science and Industry Endowment Fund.

1. General.

The Science and Industry Endowment Fund was created in June, 1926, and thus has been in existence for a sufficient time to render of interest a brief account of the activities that have followed its formation.

The Fund itself was established by the *Science and Industry Endowment Act* 1926, whereby an amount of £100,000 was appropriated from the Consolidated Revenue to form the Fund. The Act provides that the income obtained by the investment of that amount shall be used for the purpose of (i) granting assistance to persons engaged in scientific research, and (ii) training students in scientific research. The Fund is vested in, and placed under the control of, trustees who are the members for the time being of the Executive Committee of the Council for Scientific and Industrial Research.

The principal reason that prompted the formation of the Fund was the admitted lack in Australia of a sufficient number of research workers having an adequate training in many of the branches of science with which the solution of national problems is so closely connected. The importance of this was soon made obvious to the Council, for one of the earliest difficulties with which it had to contend—and one which has not yet been entirely overcome—was the shortage of available entomologists, plant pathologists, plant physiologists, dairy chemists, &c., which it required for its various investigations. The value of investigators experienced in such matters is obvious when the nature of the problems confronting the Australian primary producer, and caused by insect pests and plant diseases, &c., is remembered.

With a view to rectifying the above conditions, the trustees, since the formation of the Fund, have devoted a large proportion of their annual income of some £5,000 to the granting of research studentships to specially selected graduates of Australian Universities, in order that such people may obtain further training in their particular branches of knowledge. Studentships are given only to graduates who have completed their courses with distinction, and who have been specially recommended for appointment by their professors. Incidentally, each studentship is tenable for two years, and carries an allowance of £300 per annum, together with such additional allowances for travelling fares, outwards and homewards, as may be required. As a general rule, £150 covers these latter allowances. Students are required to give the Council an option upon their services for the three years subsequent to their return to the Commonwealth at salaries of £400 in the first year, £450 in the second, and £500 in the third. In addition to the above senior studentships, a system of junior studentships has been put into operation. These are intended for promising graduates who have not had the experience warranting their appointment to senior studentships. In general, appointees to the junior studentships are located at some organization in Australia, and, at the end of their period, they are considered for appointment to a senior studentship or else direct to the staff of the Council or any other body that may require them.

Those appointed to senior studentships are sent to leading research organizations in their particular field of knowledge. In general, these organizations are situated in Great Britain or in the United States of America, and a most encouraging feature of the trustees' activities has been the readiness of the authorities controlling these organizations to provide accommodation for the Australian students and to make arrangements for such students to obtain wide experience. On occasions full students are located in Australian laboratories.

As a result of the foregoing activities, a steady, though small, stream of research workers, with experience in the most modern methods of research and having an acquaintance with the leading investigators in their particular field, is now returning to Australia. Most of the returning students are intended for the staff of the Council, but some join the staffs of other research organizations in Australia, for example, State Departments of Agriculture. As the Council becomes fully staffed, the proportion of those available for appointment to the latter bodies will naturally be greater. There is thus little doubt that the Fund has rendered possible a very appreciable increase in the amount of skill and experience available in Australia for the general application of science to industrial methods.

2. Appointments to Studentships already Made.

The following appointments to studentships have already been made:—

1. *Entomology: F. G. Holdaway, M.Sc.* (*Queensland*).—He left Australia in September, 1926, for Cornell University, U.S.A. Subsequently he spent a year at the "Parasite Zoo," England, and is now in Australia on the staff of the Council's Division of Economic Entomology. *S. Garthside, B.Agr.Sc.* (*Sydney*).—He left Australia in October, 1926, for Cornell University, and subsequently transferred to the "Parasite Zoo," England, where he is now engaged in a search for parasites for use against Australian weed pests. *J. W. Evans, B.A.* (*Camb.*).—He left Australia in 1927 for the Cawthron Institute, New Zealand, and is now back in Australia as a member of the staff of the Division of Economic Entomology. *Miss W. Kent Hughes, B.Sc.* (*Melbourne*).—She left Australia in May, 1928, for further training as a coleopterist under Dr. Munro at the University of London. She is now on the staff of the Division of Economic Entomology at Canberra. *Miss L. F. Graham, B.A.*, was appointed in October, 1928, for one year's training as a hymenopterist under Dr. Munro at the University of London. She is now in Canberra on the staff of the Division of Economic Entomology.

2. *Liquid Fuels: J. R. Duggan, B.Sc., B.E.* (*Sydney*).—He left Australia in November, 1926, for the Fuel Research Station of the British Department of Scientific and Industrial Research. He has now returned to Australia, and is on the staff of a private concern interested in the general question of the utilization of coal. *L. J. Rogers, B.E.* (*W.A.*).—He left Australia in August, 1926, for the Fuel Research Station of the British Department of Scientific and Industrial Research. At the present time he is in England, but will return to Australia at an early date. *H. W. Strong, M.Sc.* (*Melbourne*).—He had made arrangements to leave Australia prior to the formation of the Fund. He was given a small grant, and is now on the staff of Imperial Chemical Industries, expecting to return to Australia at an early date.

3. *Plant Pathology: Miss Phyllis Jarrett, M.Sc. (Melbourne).*—She left Australia in November, 1927, for the Rothamsted Experimental Station, Harpenden, England, but has now returned, and is on the staff of the Division of Plant Industry at Canberra. *W. V. Ludbrook, B.Sc. (Adelaide).*—He was appointed in January, 1930, to a studentship tenable at the University of Wisconsin, U.S.A.

4. *Statistical Methods in Agricultural Research: Miss Frances Allan, M.A. (Melbourne).*—She left Australia in September, 1928, for one year's training at the School of Agriculture, Cambridge University, and a second year's training at the Rothamsted Experimental Station, Harpenden, England. Prior to her appointment, she was a mathematical graduate of the University of Melbourne, and has now been appointed to the staff of the Division of Plant Industry at Canberra.

5. *Fruit Production: G. B. Tindale, B.Agr.Sc. (Melbourne).*—He left Australia in December, 1927, for the East Malling (Kent) Research Station, England. He has now returned to Australia and rejoined the staff of the Victorian Department of Agriculture.

6. *Forests Products: H. E. Dadswell, B.Sc. (Sydney).*—He left Australia in November, 1926, for the Forest Products Laboratory at Madison, Wisconsin. He has now returned to Australia, and is on the staff of the Division of Forest Products. *J. E. Cummins, B.Sc. (W.A.).* He left Australia in January, 1927, for the Forest Products Laboratory at Madison, Wisconsin. He has now returned to Australia, and is on the staff of the Division of Forest Products. *Ian Langlands, B.E.E. (Melbourne)*, left Australia in October, 1929, for training at the Forest Products Laboratory, Princes Risborough, Bucks, England. *W. L. Greenhill, B.E. (Tasmania)*, left Australia in October, 1929, for the Forest Products Laboratory at Princes Risborough, Bucks, England. *R. F. Turnbull, B.E. (W.A.)*, left Australia in November, 1929, for the Forest Products Laboratory, Madison, Wisconsin. Prior to his appointment, he had spent one year at the Forestry School, Canberra.

7. *Animal Parasitology: I. Clunies Ross, D.V.Sc.*—He left Australia in June, 1929, for six months' post-graduate study at the Institute of Infectious Diseases, Tokio, Japan.

8. *Animal Nutrition: W. A. Carr Fraser, B.V.Sc. (Sydney).*—He left Australia in March, 1929, for the Rowett Research Institute, Aberdeen.

9. *Soil Biology: E. C. Tommerup, B.Sc. (Queensland).*—He left Australia early in 1930 for the Rothamsted Experimental Station, England.

10. *Soil Chemistry: G. R. Piper, B.Sc. (Adelaide).*—He left Australia in March, 1930, for the Rothamsted Experimental Station, England, but died there three months later.

11. *Cold Storage Investigations: J. R. Vickery, M.Sc., Ph.D. (Melbourne).*—Prior to the formation of the Fund he had arranged to leave Australia for the Cambridge University on an 1851 Exhibition. A small additional grant was given to him. After obtaining an amount of experience at the Low Temperature Research Station of the British Food Investigation Board, he has now joined the staff of the Council. *S. A. Trout, M.Sc. (Queensland).*—He left Australia in August, 1928, for the Low Temperature Research Station of the British Food

Investigation Board. *F. E. Huelin, B.Sc.* (*W.A.*), left Australia in July, 1930, for the Low Temperature Research Station of the British Food Investigation Board. *N. E. Holmes, B.E.E.* (Melbourne), left Australia early in 1930 as a member of the expedition from New Zealand to study the transport of frozen meat. When in England, he was appointed to a senior studentship tenable at the British Food Investigation Board's Low Temperature Research Station.

12. *Dairy Chemistry: W. J. Wiley, M.Sc.* (*Queensland*).—He left Australia in November, 1928, for training at the National Institute of Dairying, Reading, England. He has now returned to Australia, and has joined the staff of the Council.

13. *Marine Biology: A. G. Nicholls, B.Sc.* (*W.A.*).—He left Australia in July, 1929, for the Marine Biological Station, Plymouth, England.

The following appointments have been made to junior studentships:—

1. *Plant Genetics: W. Bryden, M.Sc.*—Appointed in May, 1929, for one year's training under Dr. B. T. Dickson at Canberra. *C. S. Christian, B.Sc.* (*Queensland*).—Appointed in March, 1930, for one year's training under Dr. B. T. Dickson at Canberra.

2. *Plant Pathology: W. V. Ludbrook, B.Sc.* (*Adelaide*).—Appointed in January, 1929, for one year's training under Dr. B. T. Dickson, and subsequently appointed to a senior studentship.

3. *Agrostology: A. B. Cashmore, B.Agr.Sc.* (*S.A.*).—Appointed in March, 1930, for one year's training in agrostology under Professor A. E. V. Richardson at the Waite Agricultural Research Institute.

4. *Entomology: A. M. Wade, B.Sc.* (*Melbourne*).—Appointed in April, 1930, for one year's training under Dr. R. J. Tillyard at Canberra, but subsequently died by accidental drowning.

5. *Animal Nutrition: J. W. H. Lugg, B.Sc.* (*W.A.*).—Appointed in June, 1929, for one year's training under the late Professor T. Brailsford Robertson at the Division of Animal Nutrition, Adelaide. He was subsequently appointed to the staff of the Division.

6. *Marine Biology: A. H. Colefax, B.Sc.* (*Sydney*).—Appointed in February, 1930, for one year's training in marine biology at the Department of Zoology of the University of Sydney.

3. Assistance to Research Workers.

In addition to the granting of the studentships mentioned in the previous section, the trustees have made a number of grants to various Australian research workers, located at Universities and elsewhere, for assistance in connexion with their particular investigations. Payments of this nature are made by the trustees only to investigators of proved powers, and to enable them to devote to some specific research time which would otherwise be given to paid work. Preference is also given to persons whose careers lie in research work, and it is not intended, for instance, to assist persons who are seeking research degrees as avenues to employment which will not include research. Some fifty or more grants of this nature have already been made, covering all the various sciences studied in Australian Universities.

Ethylene Oxide as a New Fumigant for Dried Fruits.

By J. E. Thomas, B.Sc., B.Agr. Sc., B.V.Sc., Commonwealth Research Station, Merbein.

Fumigation as a measure of control of the pests of dried fruit—in particular the larvae of *Plodia interpunctella*—has been discussed in a previous issue of this Journal,* and the purpose of this article is to direct attention to the value of ethylene oxide as a fumigant.

The merits of ethylene oxide were first established as a result of the work of Roark and Cotton† in the United States, who examined some 309 aliphatic compounds to determine their possible value as fumigants. Two compounds (methyl-monochlor-acetate and ethylene oxide) were found to be highly toxic to insect pests of stored food. In brief, the advantages of ethylene oxide are—

(1) The high toxicity at low concentration (2 lb. per 1,000 cubic feet is the dosage recommended for commercial practice).
(2) The absence of any fire hazard when used at these concentrations.
(3) The low boiling point (51° F.), which renders the gas effective and highly penetrating even at low temperatures.
(4) Little danger to the operators even if inhaled for a period.
(5) No harmful effect upon the food stuff fumigated.

An interesting development has been the discovery that the toxicity of this compound is increased by mixing it with 7 to 10 times its weight of carbon dioxide. This is particularly so in the case of the fumigation of nut meats, which appear to absorb appreciable quantities of ethylene oxide.‡

Below its boiling point (51° F.) ethylene oxide is a pleasant smelling liquid miscible in all proportions with water. The specific gravity (7°/4°) is 0.887. Owing to the low boiling point, it is stored in steel cylinders, which are upended to withdraw the liquid.

The published results from the use of this fumigant elsewhere appeared to be so promising that it was decided to carry out some trials to test its efficacy against the principal dried-fruit pest (*Plodia interpunctella*) of Australia.

The material for the experiments was imported from the United States of America in 1929, but it is now available locally in commercial quantities. In these trials mentioned below, the liquid was withdrawn into a measuring cylinder and immediately placed in the bell jar or fumigating cylinder, which was then closed down. At ordinary temperatures, ethylene oxide rapidly boils away.

Eggs were collected and used to infect clean sultanas, which were then exposed to the action of ethylene oxide in a bell jar at the rate of 2 lb. per 1,000 cubic feet for periods of from 3 to 24 hours. Examination fifteen days later showed that no eggs hatched in the treated samples, whereas hatching occurred in the unfumigated samples.

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* Thomas, J. E., Dried Fruit Grubs—The Ethylene Dichloride-Carbon Tetrachloride Fumigation Process. This Journal, **2**, p. 128, 1929.

† Ethylene Oxide as a Fumigant. *Jour. Indus. Engin. Chem.*, **20**, p. 805, 1929, and Tests of Various Aliphatic Compounds as Fumigants, United States Department of Agriculture Tech. Bull. 162, 1929.

‡ Back, E. A., Cotton, R. T., and Ellington, G. W., Ethylene Oxide as a Fumigant for Food and Other Commodities, *Jour. Econ. Entomol.*, **23**, p. 226, 1930.

In order to test the penetrating power of ethylene oxide, ten lots of 25 larvae were enclosed in a small tin vessel an inch long, with wire-gauze ends, wrapped in linen and packed in the centre of tightly packed sultanas in a container 9 by 3 inches, open at each end. Five lots were treated in February-March and five in August, 1930. Exposures ran from 2 to 24 hours with 90 per cent. kill at two hours and 100 per cent. for three hours and over. At two hours' exposure, 20 per cent. were dead on opening, and the remainder up to 90 per cent. died during the next five days.

In tests with pupae none of the fumigated developed, whereas with untreated 40 per cent. developed into moths.

For a commercial test, an airtight steel drum with a capacity of 125 cubic feet, was employed. Four 56-lb. boxes of sultanas were selected, and in each box three lots of 25 larvae, enclosed in the small receptacles mentioned earlier, were buried. The boxes were re-pressed, nailed down, and placed in the drum. Ethylene oxide at the standard dosage was added, the drum closed down at 4.30 p.m., and opened at 10 a.m. next day. On opening, 70 per cent. of the larvae were found to be dead. Curiously enough, the 30 per cent. alive on opening were quite active, but all died within 36 hours. This feature of delayed death has been noted in the experiment with larvae. The temperature record in degrees Fah. were—maximum, 60; minimum, 42; and weighted mean, 50. Very probably, the lower temperatures in this experiment were responsible, in part at least, for the delayed kill.

In conclusion, although the above-noted tests have been limited in number and on a laboratory scale with respect to dried fruits, they show that ethylene oxide is an effective fumigant against the eggs, larvae, and pupae of the dried fruit moth—*Plodia interpunctella*. Laboratory tests at mean temperatures above 68° F., with a dosage rate of 2 lb. per 1,000 cubic feet, showed that an exposure period of as low as four hours was sufficient to destroy eggs and larvae in experimental packs.

(The Occurrence and Distribution of Salinity in a Virgin Mallee Soil. See page 12.)

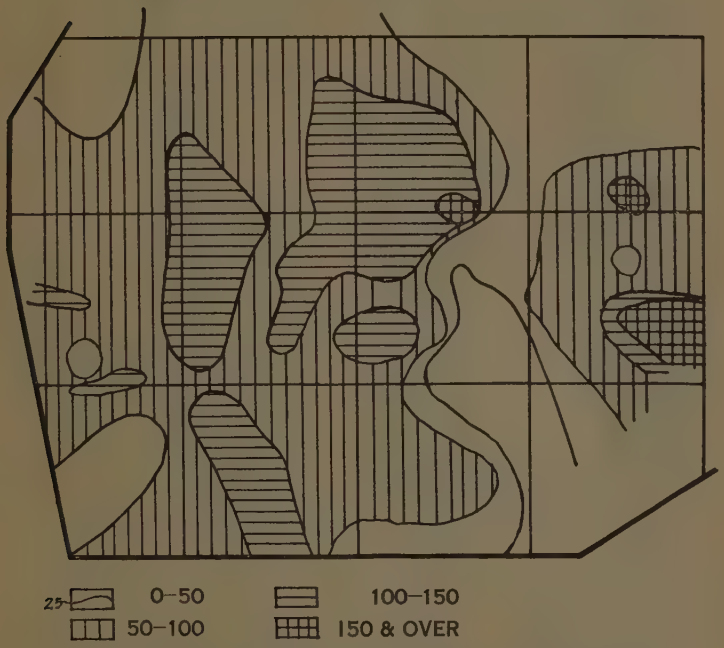

FIG 1.—Illustrating average distribution of salt to a depth of 3 feet in the area investigated. Chlorine ion: parts per 100,000 of dry soil.

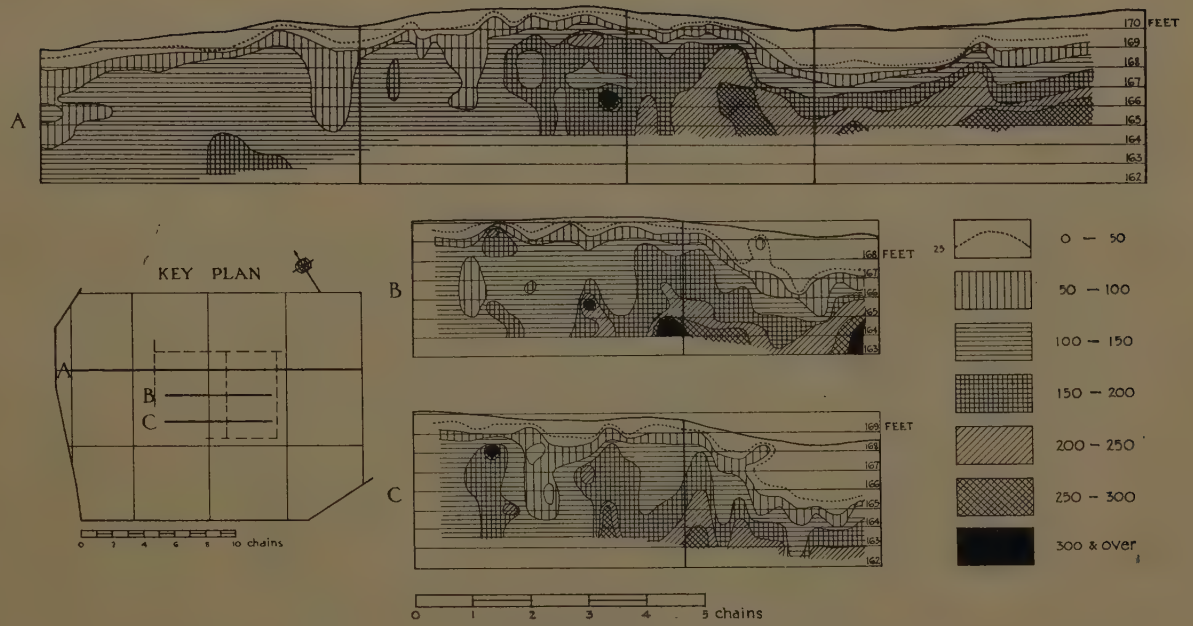

PLATE 4.

FIG. 2.—Illustrating vertical distribution of salt in three parallel sections across the area investigated. Chlorine ion: parts per 100,000 of dry soil.

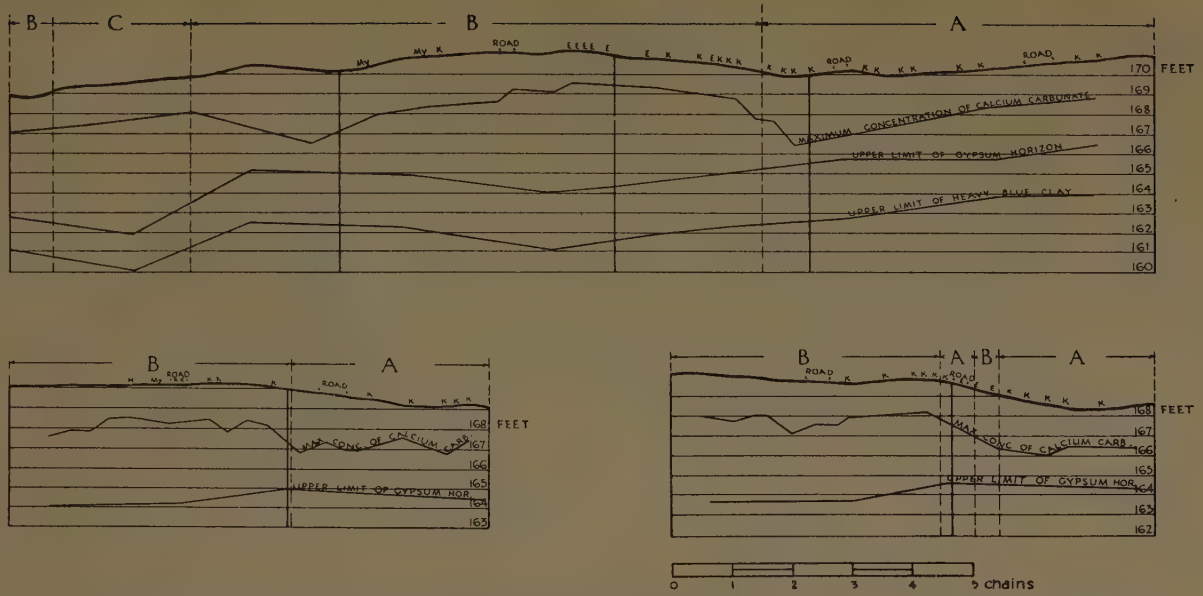

FIG. 3.—Illustrating vertical sections across area investigated. The soil types A, B, and C and principal vegetation are indicated.
K = *Kochia* spp. E = *Eucalyptus* spp. My = *Myoporum platycarpum*. H = *Heterodendron oleifolium*.

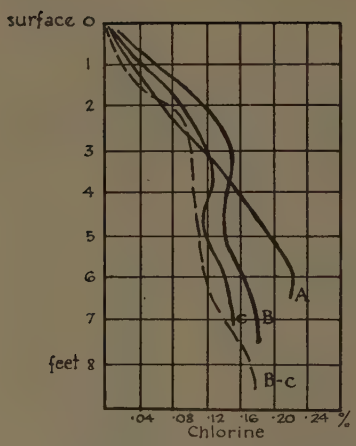

FIG. 4.—Average values for chlorides in vertical sections of the different soil types.

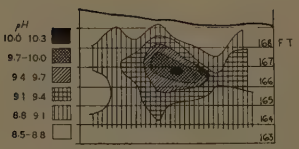

FIG. 5.—Illustrating distribution of soil reaction in a vertical section of area investigated. (Right hand of section B in Fig. 2.)

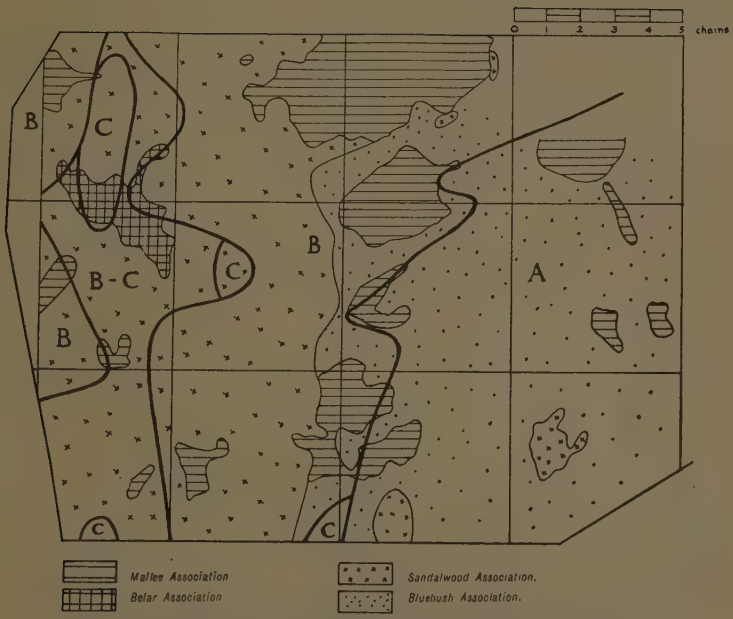

FIG. 6.—Vegetation and soil map of area investigated. Vegetation associations defined by C. Barnard.

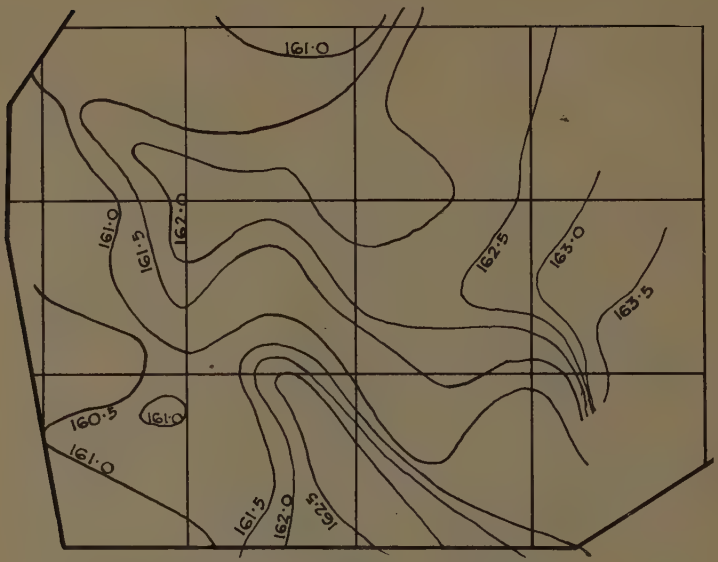

Fig. 7.—Surface contours of area investigated.

Fig. 8.—Contours of upper surface of blue clay horizon in area investigated.

NOTES.

Control of Stomach Worms in Sheep—Administration of Drugs in Drinking Water.

It has long been hoped that for the treatment of internal parasites, and especially stomach worms of sheep, some means might be devised which would make it possible to administer the necessary agent in the drinking water, thus obviating the need for mustering and drenching individual sheep, as required by existing methods of treatment. In the past, parasitologists have been unable to find any evidence that drugs given in this way are effective, and it is generally held that a drug in such dilution that it may be taken in the drinking water daily with impunity must be too weak to exercise any lethal effect on the parasites. In spite of this, pastoralists continue to hope for the development of such methods of treatment, and there is always a tendency—should any be suggested as giving beneficial results—for tried and reliable methods to be abandoned, with results which may be serious to the pastoralist.

During the past year, reports have been received from pastoralists stating that very satisfactory results have been obtained apparently by the administration in the drinking water of drugs, such as potassium permanganate, a proprietary preparation containing coal tar acids, &c., and asking that the employment of these in that manner be investigated by the Council. Since these reports were made by pastoralists of standing, on whose opinion considerable weight must be placed, the effects of such drugs given in the manner mentioned have been investigated by the Council's parasitologist, Dr. Clunies Ross.

Among the drugs tested were potassium permanganate, which was given in 1–5,000 and 1–2,500 solution, the proprietary coal tar preparation in 1–5,000 solution, copper sulphate (bluestone), in 1–5,000 solution, and a proprietary preparation of sodium hypochlorite in 1–5,000 solution. In the case of potassium permanganate, the drug was administered to sheep daily for six months in the drinking water, and, though such sheep were not exposed to re-infection with stomach worms, being kept throughout the trial in concrete yards, they were still found to contain some specimens of the large stomach worm on being killed at the end of the trial. Other sheep were given the same drug daily in the drinking water, and were re-infected experimentally at intervals throughout the trial by drenching them with young worms. Sheep so treated died in the same time as others not receiving the drug.

In the case of the other drugs mentioned, sheep were exposed to re-infection while receiving them daily in the drinking water. In all cases, it was necessary to adopt other medicinal treatment in order to prevent such sheep dying as a result of the heavy infestation set up, and against which the drugs appeared to exert no appreciable action.

The use of a 1–4,000 watery suspension of carbon tetrachloride, as prepared by Mr. Finnemore, of the Pharmacy Department of the University of Sydney, was also investigated, and, while the drug appeared to exert some action against stomach worms when given daily over a long period, there was evidence that it had definitely harmful

effects on the livers of treated sheep, and that consequently, even though possibly of some effect against the parasites, its use in drinking water could not be recommended.

Observations have also been made in the field on one property where administration of potassium permanganate in the drinking water has been extensively employed, but it was not possible to find evidence that the drug had any effect whatever in controlling infection with stomach worms, while the abandonment of drenching with other proved drugs has led to a recrudescence of the parasitic infection on this property.

The Council, therefore, considers it necessary to warn pastoralists against abandoning tried and reliable methods of treatment for stomach worms and other parasites recommended by it or the State Departments of Agriculture, and in the place of such reliable methods substituting the administration of drugs in drinking water or in the form of licks. The adoption of such unsound methods as last mentioned, while attractive superficially, will merely lead to much unnecessary expense, and will allow stomach worm infection again to become serious on properties where by regular drenching its gravity is being steadily reduced. Further experiments are now being conducted in order to determine whether it is possible to develop some method of treatment as an auxiliary to existing methods for the control of internal parasites, and which may combine some of the features hoped for from the use of the drugs specified and others.—I.C.R.

Imperial Agricultural Research Bureaux.—First Annual Report of the Executive Council.

The organization and objects of the eight new Imperial Agricultural research Bureaux was mentioned in a previous issue (Vol. 2, No. 2, p. 82). Briefly, their function as defined by the 1927 Imperial Agricultural Research Conference, which recommended their formation, is to facilitate the collection and dissemination of scientific information amongst the agricultural research workers of the Empire. Their control is vested in an Executive Council, the first annual report of which has just become available in Australia.

The Executive Council itself is composed of nominees of the different Governments of the Empire, and it elects its own chairman and appoints its own officers. To that extent the organization of the Bureaux is somewhat unique, in that in a technical sphere of work the administrative direction of activities for a common Empire purpose is vested in a body composed of nominees of the Governments, and not in one of His Majesty's Governments acting on behalf of all Governments.

The eight Bureaux, namely, those of soil science, animal nutrition, animal health, animal genetics, animal parasitology, plant genetics (herbage plants), plant genetics (other than herbage plants), and fruit production, have now been fully organized, and are all actively functioning. Their location at existing Research Institutes has enabled them to operate economically and efficiently. The various Institutes have placed accommodation at the disposal of the Bureaux on generous terms, and have assisted in numerous other ways, but particularly by making their libraries freely available, and by allowing their officers

to give advice and help on particular inquiries. Although the Bureaux were established only quite recently, several of them were able, before the close of the year, to commence the distribution (at first in mimeographed form) of information in their particular branches of agricultural science. For instance, the Bureau of Animal Nutrition has issued a collection of reprints of special interest to investigators, and also a summary of research work on animal nutrition now in progress throughout the Empire; the Bureau of Soil Science has issued a number of "technical communications," particularly in regard to soil classification; and the Bureau of Animal Genetics is issuing a quarterly journal containing a number of articles which would ordinarily be quite inaccessible to research workers in the more distant parts of the Empire.

Another object of the Bureaux is to facilitate arrangements for research workers granted "study leave" to undertake well thought-out courses of further study and investigation. All the Directors of the Bureaux would be glad to advise any investigators interested. Another function on which the Executive Council and the Directors lay special stress is that of promoting in every way possible direct contacts between officers of the Bureaux and research workers overseas. To further this end, an officer who has either received part of his early training or has served for some time in some portion of the Empire overseas, has been selected in almost every case for the post of Chief Officer under the Directors. The Executive Council hopes that research workers who contemplate visiting the United Kingdom in any year will inform the appropriate Bureau of their intention. It also hopes that they will visit the Bureau, where they will be assured of a hearty welcome.

Australian investigators desirous of further information concerning any particular Bureau would be well advised to get into touch with the appropriate Australian (official) correspondent to the Bureaux, a list of whom was given in a previous issue (Vol. 3, No. 1, p. 66).

The Control of the Eucalyptus Weevil (Gonipterus) by Parasites in South Africa and New Zealand.

Both in South Africa and in New Zealand, the introduced Australian weevils of the genus *Gonipterus* have become a very serious pest on eucalypts, which after their original introduction from Australia are now being grown in these Dominions on a fairly large scale. The first attempt to control the ravages of the beetles was made by the Department of Agriculture of South Africa, which sent one of its officers, Mr. F. G. Tooke, to Australia, in 1927, for the purpose. In Victoria (see this *Journal*, Vol. 1, p. 184), Mr. Tooke found a Mymarid parasite of the eggs of *Gonipterus*, determined by Girault as *Anaphoidea nitens* Gir., and later named independently *A. gonipteri* by Ferrière. This parasite was successfully introduced into South Africa, and has been widely distributed. Recent advices from Dr. Naudé indicate an average parasitism of 90 per cent., with a maximium of 96 per cent., in the eggs of the weevil in the rainier areas of Cape Colony and Natal; but, on the drier areas of the Highveld in the Transvaal, the parasite has not proved successful.

Dr. Naudé has been seeking for some other parasite which would be suitable to Highveld conditions. In March, 1929, Mr. G. F. Hill, of this Council's Division of Economic Entomology, discovered both Mymarid and Cleonymid parasites of *Gonipterus* eggs around Canberra, and suggested that shipments from this locality would be more likely to succeed in the Transvaal, owing to the similarity of the climate. Since then, two shipments have been made to South Africa (this *Journal,* Vol. 1, p. 378), and recent advices from Dr. Naudé indicated that they opened up in good condition. Parasites were bred from them in the ratio of about four Cleonymids to one Mymarid. The Cleonymid is apparently *Secodella viridis* Gir. It was reared and tested in the insectary in South Africa, and later on, two colonies, each 100 strong, were placed out in the Transvaal. Thus it will be seen that *Gonipterus* now appears to be controlled efficiently in the rainier parts of South Africa, while the introduction of the Cleonymid offers good hopes of control in the drier areas also.

As regards New Zealand, the first introductions were made by Dr. Miller in the North Island, in 1927, from material received from Mr. Tooke. Later on, Mr. G. F. Hill undertook the sending of further supplies to Dr. Miller, and the services of Mr. T. Greaves were utilized for collecting them in the field. When Dr. Miller succeeded Dr. Tillyard at the Cawthron Institute in Nelson, the work of rearing parasites was transferred to Nelson. Only the Mymarid has been made use of so far in New Zealand, as the climate appears to suit it. This parasite, according to latest advices received from Mr. A. F. Clarke, Forest Entomologist at the Cawthron Institute, has now been liberated in large numbers throughout the Nelson Province, and the outlook for its complete establishment there is very promising. Mr. Clarke has also informed us that he has recovered the Mymarid parasite at Cambridge in the North Island, and Dr. Miller has recovered it in Auckland, both from the earlier liberations made in 1927-28.

The position may be summed up by stating that it appears that the Mymarid *Anaphoidea nitens* is able to exercise satisfactory control of the weevil in regions of higher rainfall (which should include most of New Zealand), but that a different parasite, capable of withstanding a drier climate, is needed for the Transvaal. The Cleonymid promises to fill this requirement. The Council has been able to render both South Africa and New Zealand valuable assistance in this problem through the useful work done on it by Mr. G. F. Hill, Senior Entomologist in charge of Forest Insects Research, with the assistance of Mr. T. Greaves, who is now Mr. Hill's field assistant.—R.J.T.

(The foregoing note describes but an instance of the interchange of insects from country to country with a view to their use in the control of pests. The extent to which Australia has used insects imported from abroad is well known.—Ed.)

Caustic Vine (Sarcostemma Australe) as a Poison Plant.

A note by Dr. J. A. Gilruth, Chief of the Division of Animal Nutrition.

Recently the manager of a large sheep station in Western Queensland brought to us a small quantity of a plant which had been sun dried, and which he considered had been responsible for the death

of a number of his sheep. It was known locally as "caustic vine," and believed to belong to the Euphorbiaceae. He stated it had been tested for hydrocyanic acid with negative results. The plant was kindly identified for us by the Government Botanist of Victoria as *Sarcostemma Australe,* and not a Euphorbium. In reference to the genus *Sarcostemma,* Professor Ewart, in *Weeds, Poison Plants, and Naturalized Aliens in Victoria,* states—"The shoots of several exotic species are edible, and it is possible that the poisonous properties of our native species have in many cases been exaggerated." In Pamel's *Manual of Poisonous Plants* 1910, Part II., p. 696, it is stated—"The caustic bush . . . *Sarcostemma Australe* of Australia is regarded in that country as poisonous." However we can find no evidence of experimental work having been carried out to determine the question. The manager referred to reported that he had frequently observed sheep partake of the plant and die soon afterwards. The sample received was handed to Dr. Turner, our Veterinary Research Officer, stationed at the Melbourne University Veterinary Research Institute, who carried out a feeding test after saturation with water, reporting as follows:-

> "The plant (of which there were 300 gms. or two-thirds of a pound) was cut into pieces about ½ inch to 1 inch long, and covered in a closed vessel with 1 litre (35 oz.) of water. It was allowed to steep for two and a half days, the week-end having intervened. A slight degree of fermentation was then occurring.
>
> Sheep V.66 was given by mouth about 500 cc. of the supernatant fluid at 11 a.m. No symptoms were observed up to 5 p.m., but at 7.30 a.m. on the next day it was found to be very ill. Examined at 10 a.m. on that day, it was found to be lying on the right side with the abdomen distended, and the neck strongly flexed backwards; at the same time, it exhibited vigorous and fast co-ordinated running movements with the four legs. This was accompanied by stertorous breathing. The jaws were clenched, and held a few wisps of hay between them, but they could be forced open, whereupon efforts were made to close them again. The muzzle and nostrils were covered with frothy saliva.
>
> The pupils were sensitive to light in a normal manner, and the body showed normal reaction to cutaneous stimuli such as pricks. The conjunctiva was markedly congested. Soft but otherwise apparently normal faeces had been passed. The heart was tumultuous, with a rapid pulse. The temperature was 105.6° F., but two hours later it had risen to 106.2° F.
>
> There were periods of comparative relaxation, during which the neck was not stretched backwards, and there were no (or only faint) running movements. Then the vigorous movements would commence again. Later, the running movements were interspersed with periods during which there were clonic spasms of the extensor muscles and arching of the neck. At 3.30 p.m., the temperature was 105.5° F. There was less tendency to the running movements, but instead the limbs were stiffly extended. A peculiar strong wagging movement of the upper ear was noticeable, and during the oscillations of the head the animal continually licked the ground.

It was killed at 4.30 p.m. by bleeding. Post-mortem showed nothing abnormal in the abdominal cavity, except gaseous distension of the abomasum and small intestine. There was a very noticeable absence of peristaltic movements. No congestion or haemorrhage, &c., were found. The lungs, except for a little hypostatic congestion, were normal. About 100 cc. of clear pleural exudate were present. There were a few haemorrhages of the epicardium of the auricles, particularly the left, and the pericardial sac was distended with about 50 cc. of clear fluid. The mucous membrane of the turbinate bones was cyanotic. The brain showed no recognizable abnormalities.

It thus appears that, apart from a little endothelial poisoning, as shown by the pleural and pericardial exudates and the epicardial ecchymoses, and paralysis of the stomach and intestines, no other obvious signs were present. There was a complete **absence of local effects in the alimentary canal.**

The poison evidently acts mostly on the central nervous system, giving rise to inability to stand, without, however, complete paralysis, for vigorous and co-ordinated leg movements were present. The stretching backwards of the neck and head, and the clenching of the jaws indicate an irritation of the spinal nervous centres concerned. The presence of the corneal light reflex, and the usual response to cutaneous stimuli, indicate an absence of any **narcotic principle in the plant.**

The rise in body temperature may be taken as a consequence of the violent and prolonged muscular effort. The salivation may have been due to inability to swallow or to some principle in the plant."

There is, of course, a possibility that the slight fermentation which occurred while the plant was being steeped in water may have caused the development of some poisonous principle, but it is unlikely. However, arrangements have been made for securing a larger supply of the plant in a rapidly sun-dried condition, when further tests will be made. I shall be glad, meanwhile, to receive any information regarding mortalities which have been suspected as due to eating this plant.

Bracken Fern—Its Possible Control by Insects.

In many parts of Australia, the bracken fern constitutes a rather troublesome pest owing to the expense involved in its eradication. Any means whereby that expense could be reduced—as, for instance, by the use of insects or diseases—would thus be of no little value.

The Division of Economic Entomolgy has been in touch with entomologists abroad in regard to the problem, and has now ascertained that two varieties of likely insects exist in Canada. One of these is a stem-boring caterpillar, and thus an insect capable of doing considerable damage to the weed. The other is not so promising. The caterpillar, however, has in Canada only one brood each year, and hibernates in the egg stage, so it is not at all clear whether it would acclimatize in Australia.

With a view to obtaining as much information as possible regarding the life history and plant food of the above two insects, the Division is now approaching other entomologists who have investigated them. In the meantime, a small portion of one of the Canberra insectaries is being planted with bracken fern, so that the insects may be studied in Australia under quarantine conditions, should it be finally decided to import supplies from Canada.

It will be realized that the proposal is quite in the preliminary stages. In any case, ferns in general are little attacked by insects, and control by such an agency is difficult. Moreover, bracken is the toughest and most resistant of all ferns to insect attack. It would seem that no type of frond-feeding insect would be of any avail against it, and that by far the greatest chances of success lie in the discovery of a satisfactory root or stem borer.

"Wood Taint" in Butter.—Australian Investigations.

From time to time in the past, the so-called "wood taint" has appeared in Australian shipments of butter overseas, and the prices realized have been correspondingly reduced. In the absence of full information regarding the cause of the taint, the formulation of adequate and economic control measures has been impossible. Some authorities consider that the condition is caused by the use of certain varieties of timber in the construction of the butter boxes, while others maintain that it is a condition peculiar to the particular churning of butter itself.

The Council has now decided to make a thorough investigation of the whole problem, and with that end in view use will be made of the services of a science graduate of the University of Queensland—Mr. W. J. Wiley—who has just returned to Australia. Prior to his return, he spent two years at the well-known Dairy Research Institute, Reading, England, as a post-graduate student under the provisions of the Science and Industry Endowment Act. He is thus well versed in modern methods of dairy chemistry and dairy bacteriology.

A small Committee, consisting of Mr. I. H. Boas (Chief of the Division of Forest Products), Mr. P. J. Carroll (Dairy Expert, Commonwealth Department of Markets), and Associate-Professor W. J. Young (Biochemistry Department, University of Melbourne), has been set up to assist the work. An amount of additional knowledge on the different factors which may relate to the problem will thus be available to Mr. Wiley. The latter has already commenced his preliminary inquiries on the problem, and has spent some weeks studying a mass of information kindly made available to him by the Department of Agriculture and Stock in Queensland, and by the Queensland Forest Service.

Bunchy-Top Disease of Bananas—Non-Existence in Western Australia.

In the Council's *Bulletin* No. 30, dealing with the bunchy-top disease of bananas, and issued in the year 1927, the following passage occurs:—

> "Bunchy-top has a comparatively wide distribution among banana-growing countries. In Australia, the disease is well

developed in north-eastern New South Wales and south-eastern Queensland, and is present also in isolated centres of banana areas in North Queensland. As infected suckers were sent from Queensland during 1925 to the North Gascoyne District of Western Australia, there is little doubt that the disease is also present in that State."

During the few years that have elapsed since the issue of the Bulletin, however, evidence has been obtained indicating that the prophecy that bunchy-top would be present in Western Australia has fortunately not come true. Several firms have recently commenced banana cultivation on a commercial scale in the Carnarvon District of Western Australia, and naturally the local State Department of Agriculture made every effort to prevent the serious disease under discussion being introduced into the State. It has recently directed its Tropical Adviser, who is stationed in the northern portion of the State, to make an investigation with a view to ascertaining whether bunchy-top was present in any of the plantations. This investigation has recently been completed, and, as a result, it has been ascertained that there is no trace of the disease in any of the plantations. The Tropical Adviser in question has had a great deal of practical experience in connexion with banana growing in Queensland, and is therefore thoroughly conversant with the disease. His evidence is all the more reliable by reason of that fact.

Second Imperial Botanical Conference, 1930.

The Second Imperial Botanical Conference was held in London on the 15th August, 1930, or one day prior to the important International Botanical Congress. In his introductory remarks, the Chairman, Dr. A. W. Hill, C.M.G., F.R.S. (Director of the Royal Botanic Gardens, Kew), pointed out that, as a result of a grant made by the Empire Marketing Board, it had been possible for the Gardens under his control to send botanical collectors to a number of far-distant countries (the botanical species of plants obtained by these collectors will be returned to Kew for examination, during which their economic possibilities will be determined). Arrangements had also been made for one or two exchanges of staff as between Kew and the Dominions. In the case of Australia, an exchange was already in existence, an Australian botanist (Mr. W. D. Francis) from Queensland being now at Kew, where he was affording valuable help on the Australian flora, and his place being taken in Queensland by an officer of the Gardens particularly experienced in the classification of grasses. Finally, Dr. Hill pointed out that, although the staff at Kew had been increased, the increasing amount of interest in botanical matters being taken throughout the Empire had resulted in very large increases in the amount of plant material sent to Kew for identification.

A number of resolutions were passed by the Conference, including one emphasizing the importance of increased opportunities for personal contact between botanical investigators in different parts of the Empire. Another included a recommendation that a series of handbooks on the vegetation of the Overseas Empire should be issued, and that the British Empire Vegetation Committee be asked to initiate this series by preparing a sample handbook on some part of the Empire. It was

reported at the Conference that a list of new genera of fungi was in course of preparation at the British Museum. Other matters to which attention was given related to the need for improved facilities for research in forest pathology, and to the training of botanists for Imperial work.

The next Imperial Conference will be held in England in 1935, just prior to the International Botanical Congress which will be held in Holland.

Imperial Agricultural Research Conference—Postponement.

In a previous issue (Vol. 1, p. 154), an account was given of the Imperial Agricultural Research Conference held in London in 1927, and it was stated that the next Conference would be held in Australia in 1932. The 1927 Conference was the first of its kind ever held, and very important results followed, probably the most outstanding being the formation of the new Research Bureaux mentioned elsewhere in this issue.

The whole question of the 1932 meeting was recently discussed by individual members of the Australian delegation to the recent Imperial (Economic) Conference with some of the British and the Dominion authorities concerned. As a result, it was generally agreed that the proposed meeting in 1932 could well be postponed. That has accordingly been done, and the time of the next Conference and its venue are at the present time in abeyance.

Return of Dr. Rivett.

After a visit to Great Britain of some six months' duration, the Chief Executive Officer of the Council, Dr. A. C. D. Rivett, returned to Melbourne per the R.M.S. *Moldavia* on the 5th January. Whilst abroad, he discussed with the appropriate authorities a number of investigations such as those concerning the storage and transport of foods, fuels, wool, &c., in which close co-operation between the producing country on the one hand and the consuming country on the other is particularly necessary. He also visited a number of research organizations in Great Britain, and thus made contacts with directors of research and with individual investigators which will be of considerable help to the Council in the future. In addition, he had several discussions with the authorities of the Empire Marketing Board, particularly in regard to the investigations in which the Board is already co-operating with the Council and to those in which it may co-operate in the future.

At the request of the Prime Minister, he was also attached to the Australian delegation to the Imperial Conference, and, as a member of the Research and other sub-committees of the Conference, afforded help in connexion with the numerous scientific matters to which the Conference gave its attention.

Important Parasites of Sheep and Cattle found present in Australia for the First Time.

During the past few months two important parasites of sheep and cattle have been recorded from Australia for the first time. One of these—the common hookworm of cattle (*Monodontus phlebotomus*)—was first found in cattle killed at the Homebush Abattoirs by Dr. G. Kauzal, Pastures Protection Board Research Officer, who is working at the University of Sydney Veterinary School, and was determined by Dr. I. Clunies Ross, Parasitologist to the Council for Scientific and Industrial Research. Since the first finding of this parasite it has been recovered from calves on several occasions, and there are indications that its occurence is widespread. The cattle hookworm is a blood-sucking parasite and in other parts of the world is of considerable economic importance since, when infestation is heavy, it may cause serious interference with the health of affected animals and even actual mortality. Investigations will be carried out by the Council to determine the distribution of this parasite in Australia and its importance to the cattle raising industry.

Dr. Clunies Ross, during a recent visit to Tasmania, also found that in sheep on the East Coast, another parasite which has not been reported previously from Australia was present in sheep examined by him. This parasite, *Oesophagostomum venulosum,* is closely related to the nodule worm of sheep which is of such importance throughout a large part of Australia, especially in Northern New South Wales, and Southern and Central Queensland. Unlike the nodule worm, however, this worm does not give rise to the formation of nodules in the large bowel, hence its presence may be unsuspected even though existing in large numbers. It is considered that this parasite may seriously interfere with the health of infested sheep and that the finding of it may lead to the explanation of certain obscure cases of unthriftiness in young sheep in certain districts. Preliminary investigations in regard to the control of this parasite and the nodule worm are being carried out by the above-mentioned officers at the University of Sydney. A detailed description will appear in a later issue of the Journal.

Recent and Forthcoming Publications of the Council.

Since the last issue of the *Journal,* the following publications have been issued:—

Bulletin No. 46.—"Studies on Black Disease (Infectious Necrotic Hepatitis in Sheep)," by A. W. Turner, D.V.Sc.

The following publication is now in the press:—

Pamphlet No. .—"The Influence of Frequency of Cutting on the Productivity, Botanical, and Chemical Compositions and the Nutritive Value of Natural Pastures in South Australia," by Dr. J. G. Davies, B.Sc., Ph.D., and A. H. Sim, B.Sc., B.Ag.Sc.

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